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ABSTRACT

A year-long study was conducted with a class of 25 eighth graders, their English and science teachers, and the school computer supervisor at a school in Roselle (New Jersey). The structure and goals of the project, called PULSE, for Pupils Using Laptops in Science and English, are described. Research questions focused on the development of teachers' goals and practices and their relation to the technology, the development of project-based activities, the development of student writing skills, and the impact of local telecommunications on teacher and student interaction. A high level of student and teacher motivation, the role of the teacher in facilitating student use of the technology, and an increase in technological competence were themes that were significant in the positive experiences of teachers and students. The portability of the laptops and the availability of integrated tool-based software were particularly useful in science education. Most of the students used the laptops as portable diaries to keep journals, write stories, and complete assignments. A holistic measure of writing scores for a randomly selected group of students indicated marked improvement in their ability to communicate persuasively, organize their ideas effectively, and use a broad vocabulary effectively. The local bulletin board was heavily used by teachers, who also managed to leverage this project into a way of bringing other badly needed resources into their school. Seven figures and two tables present study findings. (Contains 21 references.) (SLD)

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CENTER FOR TECHNOLOGY IN EDUCATION

Year One of Project Pulse: Pupils Using Laptops in Science and English *A Final Report*

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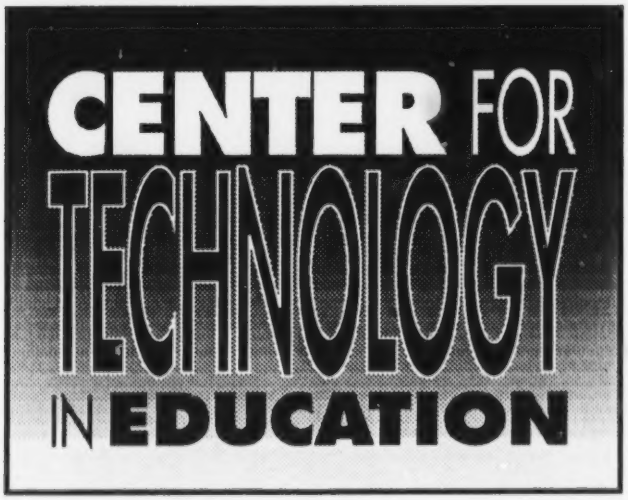

Technical Report No. 26

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March 1993

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YEAR ONE OF PROJECT PULSE: PUPILS USING LAPTOPS IN SCIENCE AND ENGLISH

A Final Report

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EXECUTIVE SUMMARY

The following report is based on a year-long study that was conducted with a class of eighth graders, their English and science teachers, and the school computer supervisor at a school in Roselle, NJ. The report is organized in four sections. In the introduction we describe the structure and goals of the project, and review the process of selecting a partner school and establishing the groundwork for the project. The second section presents the research questions and findings, which focus on five topics: the development, over time, of the teachers' goals and practices and their relation to the technology; classroom interactions among students and teachers in relation to the technology; the development of project-based activities, particularly in science; the development of students' writing skills; and the impact of local telecommunications on patterns of teacher-student interaction. The third section discusses the technical constraints that influenced the growth of the project. The final section outlines the teachers' initiatives for expanding and building upon the work of the first year of the project.

• The themes that emerged as most significant to the students' and teachers' positive experiences of the laptops as tools which facilitated their work include a high level of student and teacher motivation, the role of the teacher in facilitating and encouraging students' active appropriation of the technology, and a steady increase in technological competencies among the teachers, particularly with regard to telecommunications.

• The portability of the laptops and availability of integrated tool-based software made it possible for the science teacher to undertake long-term, collaborative science projects with the students. This represented a significant departure from the previous years' curricula and, as a result, students were able to gain experience with the kinds of tasks and procedures involved in scientific inquiry.

• For the majority of the Project PULSE students, the laptops functioned as portable "diaries" in which they were able to keep personal and teacher-assigned journals, write stories, and complete assignments. Privacy, portability, and constant availability freed students to integrate technology into personal, not just school-based, projects. Consequently, students wrote much more than in previous years.

• Based on a holistic measure of writing scores for a randomly selected group of students, they improved markedly on their ability to communicate persuasively, organize their ideas effectively, and use a broad vocabulary accurately.

• The most significant changes that the teachers reported regarding the impact of technology on their practices included an ability to undertake more inquiry-oriented and project-based activities with students, and the opportunity to communicate among themselves and with their students during off-hours through the local bulletin board system.

• The local bulletin board was used actively throughout the school year. Over a ten-week period, there was a total of 735 logins: 63.4% of these were students, 20.9% were teachers, and 15.6% were research staff. Over the course of five month, 5670 messages appeared, the majority posted by a core of approximately 25 students, teachers, and staff out of a total of 45 registered users.

• The teachers have managed to effectively leverage this project as a way of bringing other badly needed resources into their school. Their initiatives have produced a grant from New Jersey Bell to install additional phone lines; a grant from JVNCNet providing no-cost access to the Internet; a grant from New Jersey BISEC (Business Industry Science Education Consortium) to further develop inquiry-based science curriculum; and selection as a participating site in TERC's Global Laboratory, a year-long international research and telecommunications project.

INTRODUCTION

Sally Boyd's eighth grade English class is working on openings for mystery stories. Chris, who is very shy about his writing, has the screen of his laptop computer tipped down so no one can see it but him. Adrianna has passed her computer to a friend at the next table—she wants to know what she thinks of the opening paragraph. Cassie has taken her computer to the teacher; she needs help finding the right words to describe the scene she wants to set. Alrissa and Kijuana are tipping Kijuana's screen back and forth between them, writing notes to each other. Alrissa needs to borrow a disk to save her work—she finished her homework in the car this morning, and left her disks on the front seat.

The students in this scenario were eighth graders at Abraham Clark Jr/Sr High School in Roselle, NJ during the 1991-1992 school year. Together with their English and science teachers, the school computer coordinator, and researchers from the Center for Children and Technology at Bank Street College, they were the Project PULSE team (Pupils Using Laptops in Science and English). Project PULSE is part of the *Laptops for Education* program sponsored by the Panasonic Systems and Communications Company. Using laptop computers equipped with basic software tools, an electronic bulletin board system, and internal modems, these students and their teachers used the computers at home and at school for academic work, personal projects, family activities, and telecommunications. For the students, this project afforded an opportunity to take computers into their own hands—to have a year in which tools that schools usually bolt to tables and ration out rigidly were given to them to use as they liked. For the teachers, the project was a chance to experiment with interdisciplinary work, to gain experience using tool-based software in the classroom, and to expand their classroom through telecommunications. For the researchers, Project PULSE was a small but fully functioning example of a classroom with truly "personal" computers, local telecommunications capacities, and teachers and students who used the laptops for schoolwork, personal projects, and telecommunicating with each other and the "outside world," at home and at school, day in and day out. The laptops became important accessories in the educational and social lives of the students and teachers for the entire school year.

Choosing a Research Partner

This report represents a year of research at Abraham Clark Jr/Sr High School, conducted by researchers from the Center for Children and Technology. We used a variety of methods, including in-class observations, interviews, and projective tests, to explore the process the teachers and students went through as they appropriated this particular technology and integrated it into a specific set of classroom circumstances. Our research agenda paid particular attention to:

- the teachers' evolving understanding of the role of technology in their teaching, and of their pedagogy in general, explored through interviews;
- how the laptops were used in class—their impact on aspects of class room life including collaboration, teacher-student interactions, and teaching styles, explored through classroom observation and analysis of field notes;
- the nature of assignments given, and the quality of student work, through collection and evaluation of writing samples and lab reports;
- how the availability of local telecommunications affected communication among teachers and students.

This summary of our research documents the impact this technology has had on students' and teachers' experiences of teaching and learning. The project under investigation, Project PULSE, offers only one possible design for integrating laptop technology into schools—one which draws on the particular strengths offered by the teachers and the available technology, and which was constrained by fiscal realities and inevitable logistical limitations. While laptop computers offer capacities which might benefit any community, specific implementation choices will depend completely on the nature of the community in which they are being used.

Over the summer of 1991, staff from the Center for Children and Technology looked for a school to use as our central research site for the *Laptops for Education* project we had begun with the Panasonic

Communications and Systems Company. Panasonic's initiative was designed to provide hardware grants to several schools and support focused research at one school site. We held a nationwide search for schools to receive the hardware grants, but our dedicated re search site needed to be in New Jersey (the home of the Panasonic Company, and close enough for us to reach on at least a weekly basis).[1] Through our own network of regional contacts, we distributed a request for proposals to schools in New Jersey, received a number of proposals, and visited six schools early that summer. At each school, we were interested in trying to understand what role this project would take in the larger context of the school. Would this amount of hardware be a significant contribution to the resources of the school, or were they already heavily endowed with technological equipment? On the other hand, was technology sufficiently present in the school that there would be some base of experience to draw on, and was there any kind of technical support available? Did the school want to spread the limited number of machines out over a large group of students, or focus on some more involved project with a smaller group? Most importantly, was the school looking for an opportunity to experiment and to change, or was their goal finding more resources to bolster practices that they already felt were successful? The Bank Street approach to education advocates a child-centered, inquiry-oriented practice, and we were interested in collaborating with a school that wanted to move their curriculum in this direction.

Our priority was working in a school where an infusion of materials, support and scrutiny would make a difference to people who cared about change and about improving their schools. However, the school would have to have some capacity to support its own endeavors—in order for school innovation to succeed, new projects cannot depend solely on daily intervention by external sources or on limitless technical support; as researchers, we would support whoever we worked with in what they wanted to do, but we could not make change happen for them. So we were looking for motivated teachers, long on ideas but short on resources, who would be willing to experiment, to make changes, and to make the most of a new opportunity.

When the three teachers from Abraham Clark Jr/Sr School responded to our request for proposals, their commitment, their expertise, and their desire for change were clear. The ideas this group had for implementing a laptop program at their school were very similar to those that we thought might be most interesting to investigate. The following are excerpts from their proposal:

> [The target population will be] one eighth grade class...of students that fall between the boundaries of remediation and acceleration—your "average" student, many of whom have limited computer access. Two teachers: the science and English teachers of this class. (Students will be together for science and English and separate for other classes.) The project will remain in grade eight for both years. This means the teachers will be the same but the students will change. We feel the teacher is the primary unit of educational change and therefore want the teachers to have two full years to refine and revise their use of this technologically rich environment...

In the conclusion of the proposal, they outlined their goals for the project:

Roselle is interested in:

- determining if laptops in the classroom and home
  - alter teachers' role and/or behavior;
  - enhance student learning;
  - change class and/or homework assignments;
  - promote cooperative learning;
  - affect amount and types of computer use;
  - increase self-esteem;
- testing telecommunications as a home/school communication system for students, parents, and teachers;
- providing racial, ethnic, and linguistic computer equity, making sure computers are available to all students.

The PULSE team proposed working with one class of students who would use the laptops as their own; integrating the English and science curricula as much as possible; using the computer supervisor, Karen Warner, as a coach, advisor, and co-teacher who would be able to support the less technologically experienced teachers on a day-to-day basis; and using the new technological resources to promote a more project-based, student research-oriented kind of teaching than was common at the school. We decided to meet with them and learn more about the school district, the teachers involved, and their ideas about how such a project might be implemented.

At that first meeting, the teachers elaborated their vision of the project for us. Essentially, all three teachers expected that multipurpose software (spreadsheets, databases, word processing, calculating, telecommunicating) and some graphics software would help them expand the scope of their own curricula—make projects possible that they might not otherwise have tried, provide tools to their students that would allow them to do more with the information that was embedded in their present curriculum. Karen Warner, the school computer supervisor, was both technically knowledgeable and an experienced teacher—she had years of experience using computers creatively in the classroom and teaching other people how to do the same. Sally Boyd, the English teacher, had used computers in a writing lab but not in the classroom, and Marianne Monaco, the science teacher, had taught computer literacy classes in the past but did not have any experience using technology in her science classroom. But both Sally and Marianne were enthusiastic; Project PULSE would be something new for them, a challenge that would bring new resources to their students and keep them from "ending up in a rut."

Another important factor at that meeting was the presence of district-wide administrative support. The superintendent of the school district and the district curriculum coordinator were both there for the entire meeting, and made it clear that they would take an active role in making such a project logistically possible. They let the teachers run the meeting and they seemed to be genuinely anxious to support the teachers and to help them make a new project happen. When needs like a regular planning time for the team or a new phone line in a classroom were raised, the administrators made it clear that such things could be "taken care of." Near the end of the meeting, the superintendent asked if he could talk for a minute, and simply told us that "we need this project." To him, Project PULSE would be a sign that innovation was going on in his school, and would serve as a positive incentive to parents who were electing to take their children out of the public school system in favor of parochial education.

After that meeting, we knew that the project design and the team of teachers involved would be interesting to work with. There were also other aspects of the school that made ACHS a good place to try this project. First, the eighth grade had recently been restructured as a school-within-a-school; this offered both a manageable, well-defined community for this small-scale project and increased chances of reasonable security for the hardware. The ACHS building houses the 8th through 12th grades, but the eighth graders (approximately 200 students) have almost all of their classes, and their lockers, on a single hall which upper-class students are not allowed to enter. They have their own class principal, and their schedule is slightly different from the rest of the school, including a dismissal time 15 minutes before the rest of the school.

Another asset was the school's technical staff. Between the two of them, Karen Warner, the computer supervisor, and Palmer D'Achille, the school's audiovisual supervisor, had experience in dealing with almost every conceivable aspect of computer use in schools. Palmer was the sort of long-time staff person who becomes an invaluable part of the school—his basement office was home to every broken computer in the building, as well as sound equipment and stage lights. Palmer oversaw the bell system, the security systems, the phone lines, and was in-house stage manager, computer repair person, and informal instructor in electronics. Palmer's presence would make the inevitable repairs and readjustments minor stumbling blocks instead of major obstacles.

Karen Warner's presence was, perhaps, the single most important factor in convincing us that ACHS was the best school for the project. She embodied a combination of qualities that CCT researchers had, for some years, been referring to as "the kind of person a school really needs to make technology integration a success." Karen is both highly competent with multiple aspects of the technology—ranging from programming to troubleshooting to purchasing—and an experienced teacher. While we had every confidence in the expertise and enthusiasm of the English and science teacher, past experiences in other school collaborations had shown us that when teachers are learning about and integrating new technologies into their teaching, they need more than technical assistance (Moeller, Reich, & Bell, 1991; Brunner, 1990, 1992). Someone like Karen, while able to do the important work of a resident troubleshooter and technical consultant, was also able to work with the teachers as another experienced teacher. She played an important bridging role, helping these teachers to fit together their areas of expertise and their new technological skills, and guiding them toward valuable re-

sources and practices as the project developed.

All of these factors led to our choice of Abraham Clark Jr/Sr High School as the dedicated research site for the Laptops for Education program. We met with the PULSE team again in July, bringing each teacher a computer and a printer to experiment with over the summer. The teachers also received accounts on a regional educational telecommunications network (WNET's Learning Link), and began familiarizing themselves with the conventions of telecommunicating. At that second meeting we began to make detailed plans for security, scheduling, and logistics that would, we hoped, make the always-difficult first year with a new technology as productive as possible.

A Closer Look at ACHS

Abraham Clark Jr/Sr High School is an 8-through-12 grade public school in Roselle, New Jersey. The student body is more than 65% African-American and about 85% of the students overall are people of color. 33% of the teachers are African-American; 2% are Hispanic, and 65% are Caucasian. The school population has shrunk in recent years as increasing numbers of families choose to send their children into the parochial system. In many years, including 1991-92, the first year of Project PULSE, the viability of the school's budget has been in question for the entire school year, as local, state and federal funds fade in and out of reach. Roselle embodies the just-barely-middle-class public school system which is not destitute enough to receive special funding, and is left to survive primarily on property taxes alone.

The teacher's union is strong at ACHS, and relations with the school board are often strained. ACHS teachers worked the entire 1991-92 school year without a contract as negotiations dragged on and then eventually stalled, pending the passage of a new budget in June. In protest, the teacher's union instituted a work action which was in place from the third week of school until the end of the year, and teachers worked only their contractually obligatory hours. Consequently, parent conferences were held during school hours, and teachers who wished to have any further contact with parents or students had to do so from their homes.

ACHS was seen by the teachers we came in contact with as "laissez-faire" territory—if you choose to innovate, if you choose to experiment, you would most likely be free to do so, or even encouraged. But teachers did not seem to expect anything more than business as usual from their administration. The principal of ACHS was ill and absent from the school for the majority of the school year. The superintendent of the district visits the school regularly and works hard to keep the entire population of Roselle from transferring their children into parochial schools. Teachers who need anything out of the ordinary—to have a field trip approved less than sixty days in advance, or a phone line added to a classroom—sometimes appeal directly to the superintendent, as the district is small and no one else but the absent school principal can override standard rules and regulations.

Most of the Project PULSE students lived with middle-class parents who held service jobs—grocery store cashiers, taxi dispatchers, school secretaries. Teachers also spoke frequently about kids in foster homes, kids living with grandparents, kids bounced from relative to relative, and with some regularity about this one who was caught selling drugs, that one who had a knife in his locker. Our experience of Roselle was of a community walking a fine line of stability, with jobs, good housing, and active families out weighing the drug economy, gangs, and unemployment at least for now. The parents of one PULSE student were both working in September, one in construction and one as a secretary; in February, both were unemployed and spending all their time out looking for work.

Among the Project PULSE students, social divisions and cosmetic differences were surprisingly difficult to observe. Social groups were not strictly segregated, and many students from all racial backgrounds followed styles of dress drawn from current African-American pop culture icons. The project researcher rarely heard students speak openly about racism within their immediate community—after an incident during the spring in which a high school girl had a confrontation with the owner of a local deli who had accused her of shoplifting, students (unlike the teachers) did not speculate openly about racial motivations, even though several similar, and race-related, incidents had occurred recently in surrounding towns and been well publicized.

Academic tracking and standardized testing play a considerable role in the academic program at ACHS. The school uses an academic tracking system of four "levels," meant to correspond to academic potential,

to place students for every subject. Academic tracking is based on scores on the High School Proficiency Test or, for the eighth grade, a "pre-HSPT" called the Early Warning Test. These tests are the state's standard measures. Students also take the California Aptitude Tests, and their final exams are all mandated to be at least half multiple choice. In the classes we observed, "prepping" for these tests took up several weeks of class time—while they are not looked to as the center of the curriculum, they are considered significant enough and different enough from the content of the rest of the school year, to warrant special training for several weeks.

Getting Started

During the planning stage, our vision of the project was dominated by several issues we assumed would be important to the success of the project. These concerns were behind many of the decisions that went into the initial structure of Project PULSE. The first was security. Both the teachers and the researchers heard some dubious reactions when they described the project to family and friends that summer. Comments like "You're giving the computers to WHO? They're going to take them WHERE?" and "Well, it'll be a quick project. Those computers will disappear in the first two weeks" suggest the kind of less-than-optimistic commentary offered by casual observers. In contrast, we all shared a belief that students are likely to be as responsible as you expect them to be, and we expected that these students would want to succeed at the responsibilities of "owning" a computer. Beyond that shared belief, we simply didn't know what would happen. Consequently, we felt it was important to help the students by providing complete security for their computers during the times when they would not be using them. The teachers felt, for example, that students could not be expected to be responsible for the computers in the gym or the cafeteria, where they would be together with the older students and not as carefully supervised as in class. They also felt that expecting students to keep the computers in their lockers was asking for trouble. Additionally, we needed a secure but accessible place to house the other project hardware—a 386 Panasonic PC that was intended for desktop publishing, etc., a laser printer, and a PC which ran the local bulletin board. Other practical or technical needs included a shared classroom for English and science classes, multiple power sources for recharging batteries, and room for printers that would be accessible to students.

After much discussion and several requests to administrators, we ended up with an arrangement which turned out to serve the project extremely well. The English and science teachers shared a large classroom with enough space in the back for printers to be set up for student use. Power strips were installed along both side walls of the room, and were directly accessible from four of the seven lab tables that students sat at. A walk-in closet attached to the room was fitted with a new lock, and had plenty of shelf space for storing laptops. A former copying room, down the hall, became the "server room." It housed the peripheral hardware, and served as a meeting space, interview room, and work station for the project (see Figures 1 and 2).

The project was designed to operate independently from the existing technology resources of the school. ACHS has several writing labs and business classrooms with computers, and a computer lab in the basement where programming and "introduction to computers" are taught, and teachers bring classes of students for computer-assisted instruction from time to time. Computers range from Apple IIs to Tandys to 386 DOS-based PCs. Additionally, while only these twenty five students had laptop computers "of their own," which they were responsible for on a day to day basis all year, at the outset of the project it was clear that as occasions arose, extra computers might be used in other settings, with other students. So while the particular pattern of computer use was unique to these twenty-five students and three teachers, use of the laptops was not restricted to Project PULSE.

Although we wanted the computers to be available for flexible use in the school, we were careful to establish a shared understanding among teachers and researchers that our resources were limited and the focus of our research was a small group of students and teachers who made up Project PULSE. For example, we did not talk at length with the teachers about their other teaching responsibilities. And apart from having been specially scheduled so that they had English and science class together, the students involved in this project had normal schedules, and we had no involvement with their other classes. Although the PULSE teachers' schedules were specially designed so that they had a planning period together every day, their

Figure 1
Room 208, Abraham Clark Jr/Sr High School, Roselle, New Jersey

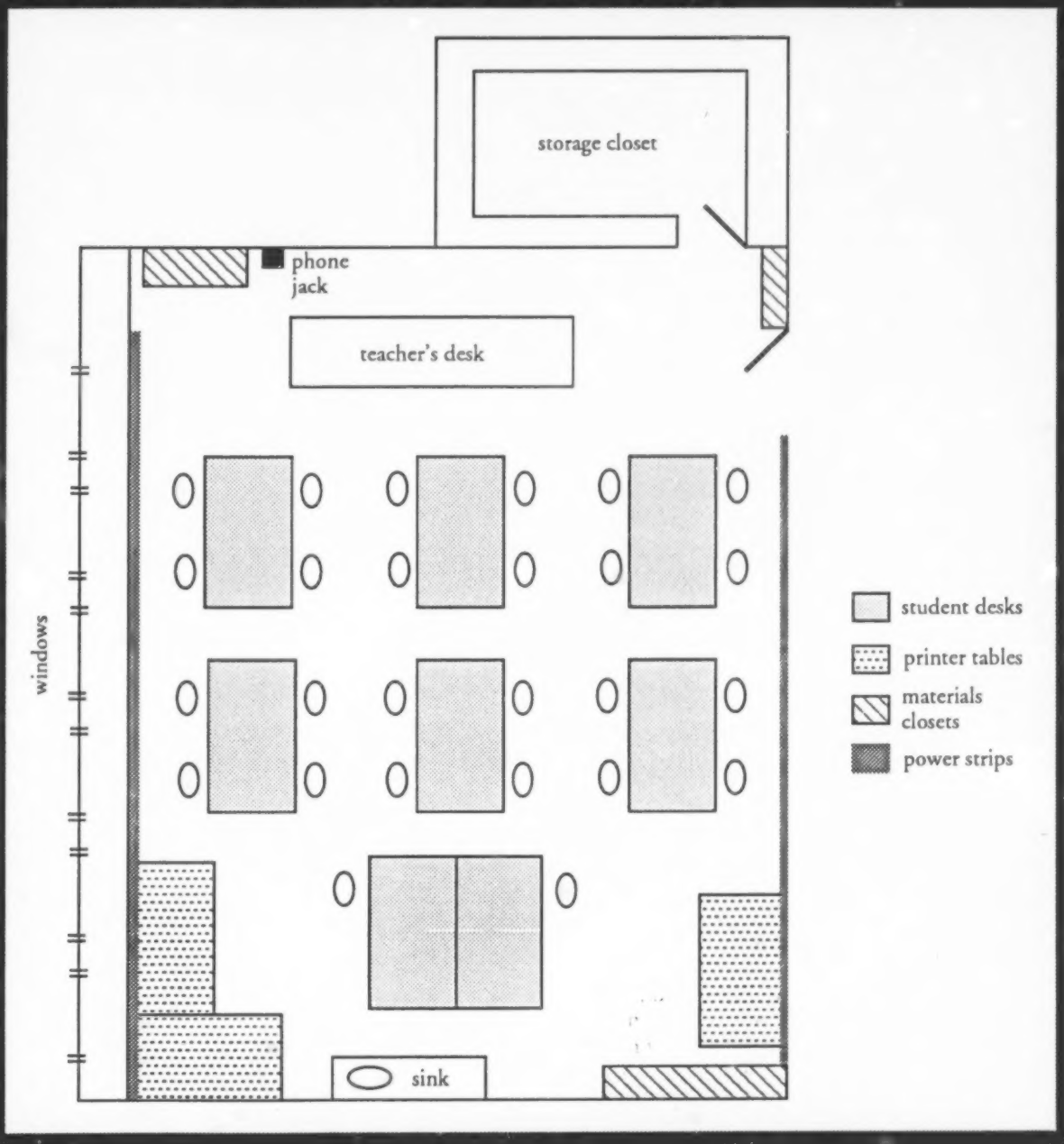
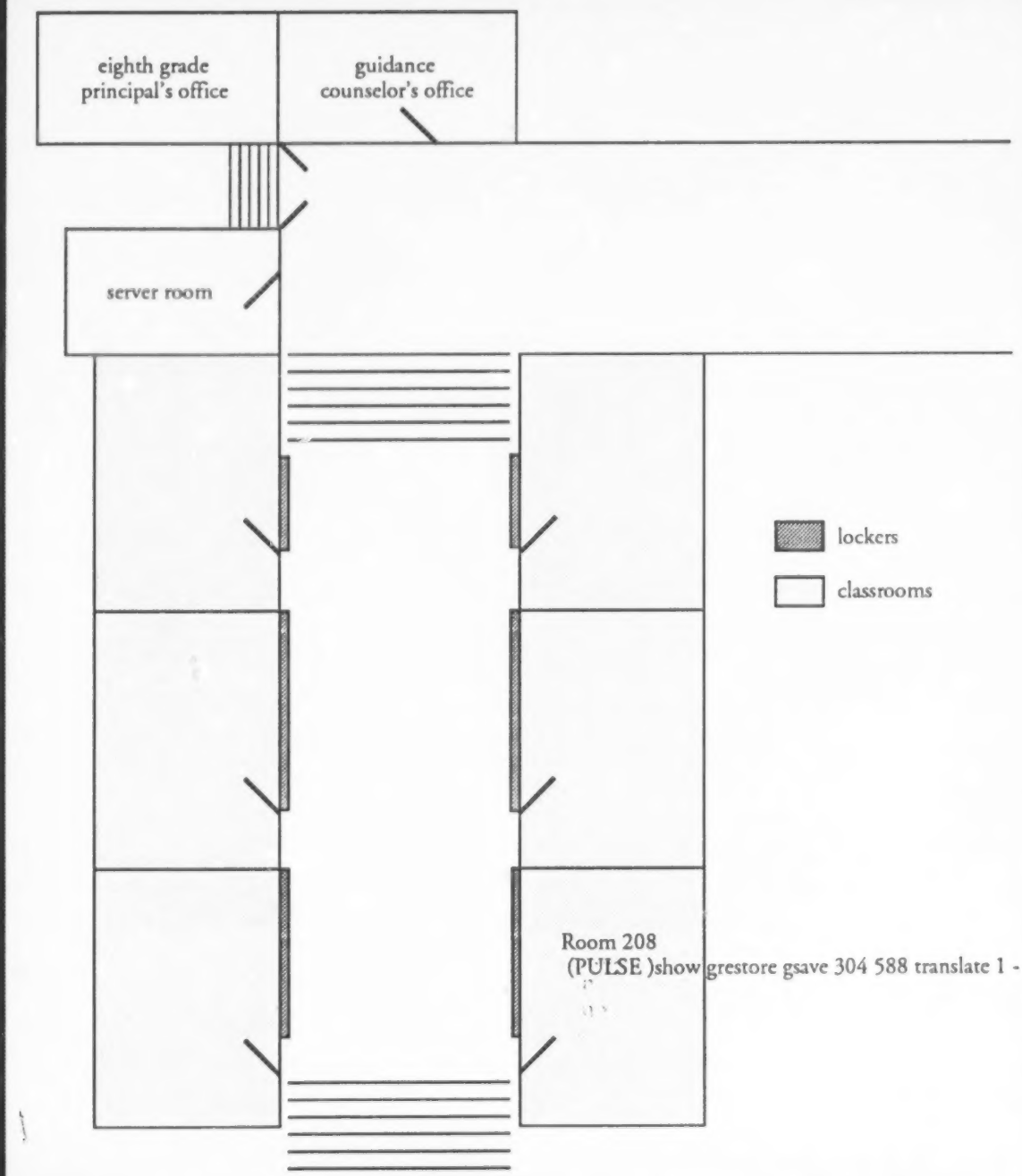


Figure 2
Eighth Grade Hall, Abraham Clark Jr/Sr High School, Roselle, New Jersey



workload and responsibilities were otherwise the same as they would have been without the project. Besides their teaching schedules, each one of them had other significant responsibilities in the life of the school; Karen, as supervisor for computer instruction, was busy reviewing and beginning to redesign the school's computer curriculum; Sally, the English teacher, was the Senior Class Advisor; and Marianne, the science teacher, advised, edited, and raised funds for the school yearbook.

A final concern was facilitating collaboration among the three PULSE teachers. While there was much less that could be done about this issue during this early stage, promoting science/English collaboration and cross-disciplinary work was a priority of the project and was on everyone's mind during these weeks of planning. Sally and Marianne both knew that there was a certain amount of curriculum that they would have to cover in the course of the year, and while we spent some time coming up with possible new collaborative projects that might take place during the year, both teachers were focusing primarily on smaller-scale cooperation. At the same time, both teachers knew that they would need a good deal of time to simply get the basics in place—to teach the students how to use the software, to teach them to telecommunicate, and to discover a routine for using the computers in class.

Scheduling needs were worked out in detail, and the administration helped to arrange schedules that would help the project work. Science was first period; second period most PULSE students had gym and could be pulled out for interviews or projects when necessary; fourth period was English; fifth period was eighth grade lunch, so the PULSE class could take a double period (English/lunch) when necessary. Fifth period was a mutual planning period that all three teachers used on a daily basis. We planned that the research assistant would visit the school once a week, observing classes, conducting interviews, providing technical support, and reviewing and planning the course of the project with the teachers.

This kind of planning continued through the first few weeks of the school year. The PULSE class had been told that they were going to be using laptop computers, but the computers were still waiting in boxes in the closet off of room 208 (the shared science/English classroom). During the first week of October, the teachers scheduled a Parent's Night for Project PULSE. That day they brought out the computers for a period. The class learned how to turn them on, and how to load a word processor, and wrote short notes to their parents. Then they packed the computers away again, this time in carrying cases, with the understanding that as long as they brought a parent to the meeting that night, they could take home a computer.

That night, the teachers came early and decorated room 208 with balloons and crepe paper, and set the computers out on the tables, with a balloon tied to each one. All twenty-five students came, each with at least one parent and many with grandparents and siblings as well. The room was overflowing. Parents met the project director and the research assistant from CCT and the project liaison from Panasonic; the school superintendent was there as well. Karen answered parents' questions, a videotape introducing the kind of research done by CCT was shown, and parents and students signed contracts out lining the responsibilities the students were taking on. Then students demonstrated their new machines to their parents. Many students loaded up the message they had written earlier in the day - one started working on a story while his mother talked with a teacher. Although one or two students and some parents seemed reserved or detached, most of the students seemed enthusiastic, proud and eager to become more familiar with the machines. "Can you believe they all came?" Karen said at the end of the evening. "Every single one of them had someone here. That never happens."

RESEARCH FINDINGS

We anticipated that what the laptops had to offer was support for changing circumstance—a set of tools, made available to teachers and students in such a way that teachers could reasonably expand the field of inquiry into areas that were previously, practically speaking, logistically unreachable. Authentic and in-depth data collection, extended writing and revision processes, collaborative writing and data analysis, for example, would become real possibilities as logistical and practical obstacles were cleared away by the presence of the laptops. And in turn, as those new projects became real, they would affect teaching practices, student performance, and classroom dynamics, leading to new ideas and new projects.

What was most important about the laptop technology—what it offered to this project—were its generic strengths, not a particular content. The capacities of these computers were all consonant with skills that students already had—writing, editing, graphing, calculating—as opposed to bringing new mediums for presentation or practice (i.e., multimedia systems for making presentations, CD-ROM for research, HyperCard for programming, or computer assisted instruction for drills). The questions raised by this project are not so much questions about the impact of particular tools internal to the technology, but rather what happens when computers as whole objects are removed from the constraints typically associated with their use. How is student work affected when, rather than doing lab work one day in a science room and data entry and analysis another day in the computer lab, computers are running on each table during the experiment? How are teachers' interactions with students during the writing process affected when students "own" their computers, and are able to work with the computer in their lap, or with the screen turned down, or with a screen passed back and forth between students or passed around the room? How do two eighth grade boys and two eighth grade girls with four computers available on their lab table negotiate a group project that involves collecting and analyzing data in a single spreadsheet?

The features of this project that make it unique are student ownership of the technology, the portability of the machines, and telecommunications capacities. These inherent characteristics of the project design interact with our central research topics—student learning, teachers' teaching, and the nature of teacher-student relationships. The goal of our data collection and analysis was to better understand patterns of influence and interaction among the design variables unique to this project and changes in student, teacher, and family educational practices.

Teacher Interviews

Methodology

There are a number of studies that suggest that the ways in which teachers adopt innovations is directly related to their underlying pedagogical goals and beliefs (e.g., Clark & Peterson, 1986; Shavelson, 1983; Shavelson & Stern, 1981; Shulman, 1987). More recently, this inquiry has been extended to look at the ways in which teachers' pedagogical goals have an impact on their adoption and use of computer-based technologies (Honey & Moeller, 1990). This research demonstrated that there is a relationship between teachers' educational goals and objectives and the ways in which they integrate computer-based technologies into their on-going classroom practices. Teachers who succeed at making computers an integral part of their curricula tend to be highly motivated individuals, who are interested in continuing to grow and develop as professionals, and are willing and eager to learn from their students. They embrace pedagogical practices that are student-centered and progressive in nature, and they believe that student learning should be inquiry-based and relevant to the real problems and challenges that today's students face.

At the outset of our collaboration with the Project PULSE team we had a good idea that we were dealing with a group of teachers who were innovative, talented and motivated individuals. Nevertheless, we wanted to learn more about their pedagogical beliefs and practices. In particular, we wanted to explore how these teachers' beliefs might be related to the ways in which they would make use of the laptops as an integral part of their curriculum, and how their beliefs and attitudes might change over the course of the project.

We used a standard interview protocol developed at the Center for Children and Technology to inves-

tigate the relationship between teachers' classroom practices and educational objectives and the ways in which they choose to integrate and deploy technology as part of their curricula (Honey & Moeller, 1990). Although the central focus of this component of the research was on the two classroom teachers, we interviewed Karen Warner, the Project PULSE coordinator, as well. Karen had received her Master's degree from Bank Street College and we knew that she shared many of Bank Street's views on integrating technology into the curriculum. Although Karen was not directly responsible for teaching the PULSE students, she played a central role in shaping the overall design and implementation of the project.

The interviews were in-depth in nature and covered the history of each teacher's involvement with teaching, the practices they employ in their teaching, the nature of the subject matter they teach, their experience with and attitudes toward technology, and their goals and expectations for the laptop project. We analyzed the interview data thematically and descriptively, paying particular attention to the issues most relevant to our understanding of the PULSE Project: the ways in which teachers characterize their practices, goals and objectives, and their expectations for the technology that would be part of Project PULSE.

Findings

Educational Practices

Initial interviews

At the outset of the project the teachers shared a basic belief in the importance of getting their students to think for themselves. They were not interested in students parroting back information to them, but wanted students to be able to reason, conjecture, and think critically. However, the teachers differed in terms of what they discussed as educational goals and objectives for their students and their teaching.

In her first interview, Sally Boyd, the English teacher, described her pedagogy as focusing on two principal issues. The first was the theme of responsibility—she wanted her students to know that they were accountable to her and were responsible for completing the assignments she gave to them. When asked to describe her goals and objectives for a typical day in her classroom, Sally said:

> I like to come and review the homework, what it was. I might ask them a few pop questions about it, or we might just discuss it. I want them to know that if they have a reading assignment, for instance, that if I don't ask them to write something, it doesn't mean that I'm not going to check up whether they did it. And after we've done a little pop question, then we might do a do-now type of situation where they might write a paragraph...

The second theme in Sally's teaching was the importance of having her students write and think about real-world issues. Sally believes that her students have a responsibility to know what is happening in the world around them, and part of what she attempts to do in her teaching is bring the world of current events into the classroom.

> I will give a lot of lessons within what we're doing, and try to make it relate to what is happening around us. I remember as a high school student, myself, I can remember the frustration of my senior history teacher, that he didn't know anything that was happening in the world around us. And nowadays, you really do need to know, I mean the world is just so much smaller, more so even than when I grew up, you've got to know what's happening.

Marianne, in contrast, talked less about the specific tasks she wanted students to accomplish and more about setting the tone and feel of her classroom. Her educational goals centered around creating an atmosphere in which students would feel comfortable learning from one another and from their teachers. She spoke about students developing positive feelings about themselves and their peers.

> I would hope that every student would come into my classroom feeling comfortable; they would have a sense of learning not only from me but from each other; they would know that their education was important to me; and that I'm the kind of person who wants them to respect each other and grow as human beings in addition to maybe learning about science or learning about family life, I want - I would hope they come away with feeling good about themselves, and "I accomplished this today," and they can learn from each other and learn from me, and we can all learn from each other, and I can learn from them, too.

Karen spoke about her goals and objectives for the computer literacy and programming classes she teaches. Karen views herself as a facilitator whose focus is on helping students use the computer as a tool in a range of everyday circumstances.

> In the computer literacy course my goal is just that

> the students view the computer as a tool and are able to use it as a tool in their everyday life. And the PASCAL course, it would be that they come away with an appreciation and a certain sense of achievement in programming. And some of them will pursue the AP exam on their own. So as much help as I can give them toward that, that would be my goal — that I can provide them with as much preparedness as possible within the scope of that class.

Follow-up interviews

In our end-of-the-year conversations with the teachers slightly different issues emerged. Sally's focus shifted from an emphasis on helping students learn about responsibility and delivering relevant content to them, to creating a climate in which students can more directly voice their concerns and interests in relation to the material being studied. Her stated objective in the follow-up interview was to keep students interested and motivated:

> Now more than ever I realize that variety is important, and that you've got to get the kids involved in a way that they have some input into it. It has to be of some importance to them. And if it isn't then they're not going to go for it much at all. And you really have to gear your teaching toward finding things that are going to be of interest to them. And that the teacher is not the person just up there giving information out to the students...

Marianne, in her follow-up interview, painted a more specific and detailed portrait of her educational goals and objectives, this time focusing on collaborative, group based work—processes that she had stressed in her teaching throughout the year.

> I want the kids to be involved in some kind of project, and I like them to see that there's some kind of connection between what we're doing and the real world, although I'm not really sure that happens all the time, but my ideal would be that they're working on some kind of project in small groups and there's interaction between them, there's interaction between each other, there's interaction between me and individual students as well as groups, and hopefully we all come to some kind of conclusion together. And I learn from them and they learn from me, and each other.

Karen spoke most directly about changes in her thinking regarding how students learn—changes that centered on having students do more in-depth, project-based work.

> I don't know if it was just the course of this year or an evolution, but I think that one thing would have to be "less is more." Not trying to cram—I always used to feel a compulsion to cram in as much as I could, and get them out of there knowing everything, and you really end up with students walking out knowing not much of anything. So that's why I really like the project approach, the real world oriented projects; so maybe you can say oh, I didn't do forty seven thousand projects this year, but I did one project that was really done in depth and all facets were explored and kids really understood what they were doing and how to picture "you know I am doing this, and I'm collecting data for this project, and I found out things and I really learned something by discovering it on my own." I'd have to say that's the main change in my approach, less is more.

Technology-Based Goals and Objectives

Initial interviews

At the outset of the project, Sally (the English teacher) talked about the challenge that Project PULSE represented to her as a professional and the challenge she hoped it would bring to her students. In particular, the laptop project signified an occasion in which she could help her students develop and refine their writing skills. Previously, word-processing was an isolated activity which she taught to full classes, for full periods, in separate "writing lab" classes, as distinct from regular English classes. In contrast, word processing was now one of the full range of activities which any number of her students could engage in, during English class, for any amount of time, according to her direction or at their own discretion. Consequently, writing was a fluid part of the activity of the classroom, particularly during periods which were devoted to independent work on a number of different projects (which occurred frequently).

> First of all I want them to feel comfortable using the computer. And for them to enjoy writing more through the use of the computer. And to enjoy it because they'll become better at it... being a believer in the writing process—editing and then revising—it's just going to be so much easier for them on this computer. And for them to realize that a good writer doesn't just write one draft, with this you're going to be able to make revisions throughout. I think this is going to be fun for them.

Marianne (the science teacher) emphasized the ways in which the laptop project could support stu-

dents in independent inquiry and experimentation. She stressed the tool-based aspects of computer and the ways in which the technology could support data collection and analysis processes.

> I'd like them to be able to think, which is something that you might think that's what education's all about, or at least it should be about, but a lot of times the kids come up here and they just - they don't have the resources to actually learn or know how to think or to solve a problem, or how to attack it. I'm hoping that the laptops will help us do that. Show the kids that this is a tool that will help you in analyzing something, what happens if, and make them better scientists, better detectives, data-gatherers, a tool that they can use in every aspect of my science room. Hopefully. You know, they do an experiment, all their data can be recorded on the computer, they can share it with each other, I hope that's what's going to happen.

As the PULSE project director, Karen discussed the impact the project would have on several different constituencies.

> I think it's a project that is going to enhance the esteem of a number of groups. It's prestigious for the district to have such a project... I think everybody's excited about this, that we have this chance. So that's the first level. I think it's very good for all the staff that are directly involved, myself included, it's like a little transfusion of something good happening. Marianne and Sally feel that as well. And most important, I think it's a great great thing for the kids and their families. I think that they all feel privileged to have these laptops, and not only the laptops but they know that it's a research project as well. So that they are there, on the cutting edge, that they are doing it and they're being looked at. So what they're doing is important.

Follow-up interviews

For all three teachers, the goals and objectives they set for the technology were effectively realized. For Sally, the fact that the computers were portable and the students were able to work on them at home made a world of difference in students' written work. Not only were her students keeping pace with technological change, but they were able to use the technology as a tool to improve performance.

> I emphasize how fortunate we were that they got to take it home, in that because they were at home, they were able to write more, and they were able to revise and edit much easier, I mean I'm a big advocate of revising and editing through the computer. It's just a different ball game when compared to doing it on paper, you can just do so much of that. So I'd advocate, it really helps them improve their writing...I would say we're trying to get them more attuned to what's happening in the world around them when they get out, as far as the telecommunicating goes, too. I really do feel that this is going to be taking place all over...

In her follow-up interview, Marianne talked with enthusiasm about the ways in which the technology helped to facilitate and foster the inquiry- and research-based tasks that she had wanted students to undertake.

> I just loved how the kids, it really became like a real research project, when we were working on the seeds, when we were working on the Plastics Project, it was legitimate. As opposed to just reading about some thing, and doing a bulletin board on it or whatever, they were doing real research. And the computer facilitated that. And I think that was the best part for me. The most exciting part for sure. I wish—you know, I'm dying to find more things. Doing something, finding out what's going on, sharing your information with other people, getting information from other people, what's going on in other parts of the country, just the kids, when we were doing the plastics project, just that they were so involved. All those phone calls, finding out where our local landfills are, it's real, it's reality. That was the best part for me.

Karen discussed an aspect of the project that had an unanticipated effect—telecommunications and its impact on student-teacher relationships.

> Earlier I said that I was really impressed and would not have anticipated, didn't have in my thoughts the effect the [local] telecommunications would have on teacher-student relationships. It was a level of intimacy that either doesn't have the right setting or doesn't have enough time to develop in the classroom but did develop this way. It was a two-way relationship, not just student-to-teacher or teacher-to-student but a real two-way street. I think that was the most surprising thing to me that happened. It was also affirming to see "computer as a tool" happen, to see that yes, that it is the way to go and yes, that will happen if the kids have the resources. And I personally just felt very good giving these kids that chance. I really think that this project will have a long term effect on these students.

Discussion

The particular themes that Sally, Marianne and Karen emphasize in these year-end conversations reflect an orientation toward teaching and learning that was present at the start of the project. And, their pedagogical goals and objectives were inherent elements of the ways in which each teacher chose to deploy the technology in their classrooms.

Sally's commitment to student-centered teaching is reaffirmed in her acknowledgment of the importance of allowing students to express their own concerns and interests in relation to the curriculum. Many of the activities that students did in her class spoke to this. In Sally's class, the laptops were tools that helped students express and reflect upon their own thinking and ideas. For example, one of Sally's favorite activities was to have the students write "summary and response" pieces. After reading a section of a story, students were expected to summarize what they had read, and describe their thoughts and feelings in relation to the piece. The laptops also supported group writing projects in which students engaged with the kinds of "real-world" issues Sally felt were important for them to address in their writing. On one occasion, groups of students wrote letters to the governor about homelessness, first brainstorming on their own computers and then developing their ideas into a single, group-composed letter. Also, as she had hoped, the project was also an opportunity for Sally to grow and develop professionally. Through both face to face meetings and telecommunications exchanges with the PULSE team, Sally was able to build on and solidify relationships which were beneficial to her professionally and personally.

> So the telecommunicating was just another part of me growing. And also, its been part of something I've done a lot more in the last five years than in the past; I've made choices of who I wanted to spend time with, as far as interesting people, and other people who are interested in growing. Such as Karen. And such as Marianne. So it makes a big difference when you seek out and listen to people who are interested in growing and developing, like you are.

The hopes Marianne expressed at the beginning of the year about doing more project-based work were realized, and she used the particular strengths of the technology to make this kind of work possible. Marianne concentrated on using the computer as a tool for research, data collection, data analysis, and descriptive writing. In relation to this kind of work, the laptops became central to group interaction, and were a fluid medium for sharing information. In addition, Marianne used the technology to facilitate the kind of classroom atmosphere that she valued; she encouraged students to feel good about their developing technological expertise.

Karen's outlook on the relationship between technology use and pedagogy was an influential part of Sally and Marianne's experience. Most importantly, Karen was able to provide both *technical and pedagogical* support. For example, when Marianne decided it was time to introduce the students to spreadsheets, she asked Karen to lead the class for a day. In this way, Marianne was free to concentrate on the substance of the project with out having to worry about overcoming a new set of technical hurdles. Karen also located relevant software and other resources, partnerships with other institutions, workshops, and telecommunications projects that would be responsive to Sally and Marianne's priorities. For example, Karen helped Sally through all the phases of several writing exchange projects—finding out about projects, uploading and downloading text, compiling the final product—using both their local bulletin board and the Learning *Link* network. Karen was also able to bring additional resources into the project; for example, at Karen's request, Microsoft provided twenty-five copies of *Works* for student use, a 30-user LAN version of *Works* for school staff, *Works for Windows* and *Publisher*; through Princeton's JVNCNet she acquired an Internet connection for the school and advanced training for the teachers; and she initiated the team's participation in a number of regional conferences and workshops.

In the post-interviews, each teacher reflected with satisfaction on the impact of a year of intense teamwork on their own personal and professional development. In addition to their personal compatibility and their consistent willingness to share responsibility, remain flexible, and support each other in new efforts, each teacher recognized that there were practical factors that made their collaboration, and consequently the project as a whole, a success. Most important among these practical factors were regular planning time during the day to meet, plan, and work together, and the ability to communicate through the local bulletin board.

Classroom Observations

Methodology

Through careful observation and note-taking in classrooms, a wide variety of practices, discourses and relationships can be documented, and over time, patterns and developments can be established. Regular, detailed and systematic classroom observation by a participant-observer was a central part of the data-gathering process. The project research assistant visited ACHS on a weekly basis and attended both the science and English classes and held a meeting with the teachers. In addition, she had one period each visit devoted to meeting with Karen Warner, the computer supervisor. During the class period she kept careful track of the role that the teacher was playing, the nature of the teacher's interactions with the students, the students' interactions with one another and with the teacher, the ways in which the students and teacher used the laptops, technical problems that arose, and the overall tone and atmosphere of the classroom. The researcher entered her observation notes into a data analysis program and coded the data along seven dimensions. Each dimension was coded either positively or negatively.

These dimensions have been developed at the Center for Children and Technology for use in school-based technology research projects, and are intended to reflect certain processes, interactions and issues that we expected, based on previous work (Hadley & Sheingold, in press; Brunner, 1990, 1992; Honey & Moeller, 1990), to figure prominently in the implementation of a new technology-rich program in a school setting. Once a particular set of observations is coded thematically, the relative prominence of various themes or combinations of themes and the particular character of the incidents and interactions which were incorporated into each theme, help researchers identify patterns of development and interaction that occur during the implementation of innovative school-based technology projects. The seven themes used in the coding process were:

- Making Things Work, i.e.:

  Positive: Are the technical and logistical aspects of the program working smoothly? Are students and/or teachers able to respond to obstacles (faulty batteries, unfamiliar software) with a minimum of disruption or frustration? Are the time and space necessary for interaction and collaboration available? Are decision-making routines clear?

  Negative: Do logistical obstacles (i.e., lack of time, lack of space) impede the development of new activities or projects? Do technical breakdowns or complications cause delay or disruption of student and/or teacher activities? Do space or time limitations discourage interaction and collaboration? Are lines of communication inefficient?

- Student Collaboration, i.e.:

  Positive: Do students share information and ideas, work in groups, ask each other for assistance? Do teachers help students address group conflicts openly and productively? Are goals and expectations for group work clear to students?

  Negative: Do students avoid sharing information and ideas, isolate group members or limit interaction? Do teachers avoid or ignore interpersonal conflicts in work groups? Are goals for group projects poorly defined?

- Teacher Collaboration, i.e.:

  Positive: Do teachers ask each other for help and advice? Do they make an effort to create shared curriculum, or to do joint projects? Once it is given, do they act on each others' advice?

  Negative: Do teachers duplicate effort due to poor communication? Do individuals consistently defer to other individuals, or take charge unilaterally?

- Role of Teacher, i.e.:

  Positive: What part does the teacher play in the classroom? Does the teacher encourage and respond to all students in ways appropriate to their needs? How does she structure her class periods? Is she reflective and generative when she talks about her goals and expectations for herself and her students?

  Negative: Does the teacher make assumptions about students' abilities or motivations? Whom does she ignore? Does she resist experimentation and change?

- Motivation

  Positive: Are students responsive to academic expectations? Do they initiate activities themselves? Do they take on responsibility willingly or grudgingly? Does the technology appear to have an impact on student attitudes about their work and about themselves as learners? What about the teachers?

  Negative: Do students avoid certain experiences? Do they express cynicism or doubts about the relevance/comprehensibility of the technology and/or its relation to the curriculum? Do attitudes exhibited early in the year about work and about themselves as learners appear unchanged or worsened by the presence and use of the technology?

- Know-How, i.e.:

  Positive: Are the teachers and students able to incorporate the various technologies into their activities without major disruptions? Are teachers confident users and demonstrators of new software and/or hardware? Do students take on responsibilities for teaching and upkeep of equipment? Who teaches whom how to operate and maintain hardware and software?

  Negative: Do teachers abandon project ideas because they feel unable to cope with the technical requirements? Does lack of technical knowledge impede students' progress with activities or assignments?

- Expectations of Project, i.e.:

  Positive: How do teachers and students perceive or interpret their relation to "the project"? Do they have clear goals they want to accomplish that they feel are different from their usual routines? Do they have realistic expectations of the project staff? Do they characterize themselves as active participants in the project?

  Negative: Do students or teachers feel burdened by their idea of what the project requires of them?

Findings

Field notes collected over twenty-six school visits were coded for occurrences of each theme. The relative prominence of each theme as a percentage of the total number of observations (n=478), and the ratio of positive and negative occurrences for each theme, are summarized in Figures 3 and 4.[2]

Positive Motivation was the most frequently occurring theme in these observations (18.6%), followed by positive observations of the Role of the Teacher (15.9%) and positive Know-How (15.7%). Making Things Work was also a prominent issue (12.3% positive, 6.9% negative). Subcategories which characterize the kinds of actual activities and interactions that constituted each thematic area are detailed below.

Motivation

Positive Motivation (18.6% of total observations) represents the impact of the technology on teachers' and students' willingness to experiment and to engage in substantive exploration. The four subcategories that emerged from our observations are:

- *Fitting the laptops smoothly into life*, or taking the technology on as one's own—this includes activities that reflect a sense of ownership, that the technology is flexible and fulfills real needs (i.e., naming the computer, using it for personal, non-school related activities);
- *Initiative*, expressed as a willingness to try something new, to learn a new skill, or to take on responsibility. This includes tasks the teachers took on in order to expand the project—looking for new grant money, exploring telecommunications resources, etc.;
- *Doing more*, because of greater access to technological capacities; students working more intensively and extensively, producing more and/or better finished products; and
- *Excitement*, based on the novelty of the technology. This subcategory was common at the beginning of the project and gradually replaced with technical know-how as the year progressed.

Negative Motivation accounted for only 2.9% of the total observations. These observations were related to student disinterest and using the computers to avoid other activities (i.e., students writing notes or playing games on the laptops during class).

Figure 3
Occurrences of Themes (as percentages of total observations, N=478)

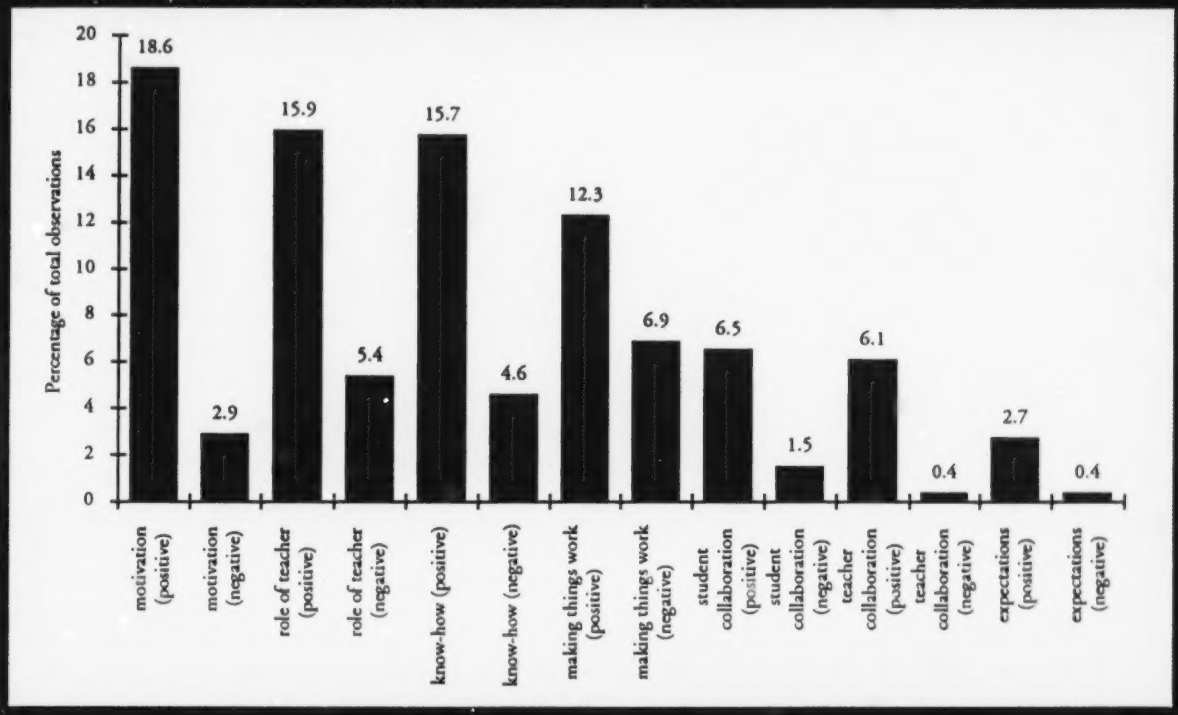
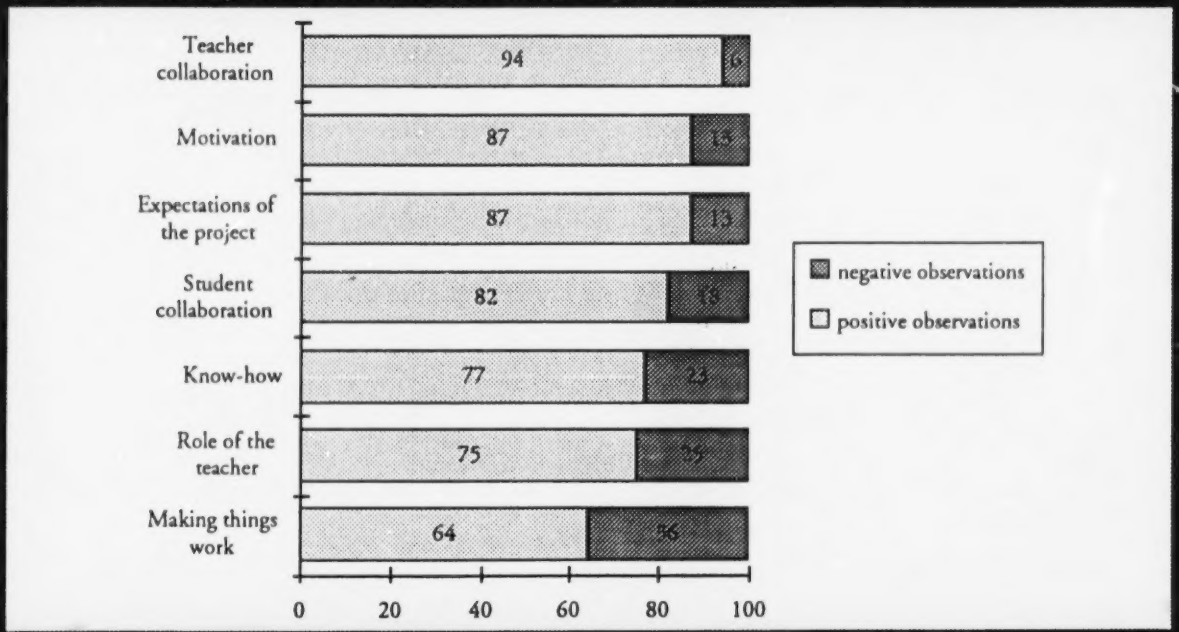


Figure 4
Ratio of Positive/Negative Observations for Each Theme Observed



Subcategories	Examples from Field Notes
Fitting the laptops smoothly into life • ownership • flexibility • responsiveness to real needs	Several kids couldn't read the board, and asked for permission to move up to the front to copy the questions. They took their laptops with them, and balanced them on the teacher's desk, on file cabinets, or on their laps to finish copying. [56] She said she...woke up at 3:30 remembering that this [lab report] was due today. So she got out her laptop and wrote it up. I asked where she was working, and she said she just sat in bed and wrote it. [301]
Initiative • willingness to experiment • willingness to take on responsibility	Marianne...got a pamphlet about a conservation essay contest for New Jersey students, and wants to post an assignment [on the electronic bulletin board] to go find out about "conservation district programs." Sally picked up on this as a possible new use for the "graphic organizers" she has been having the kids use. [153]
Doing more • working more intensively and extensively on subject matter • producing more and/or better finished products	Michelle was printing out two copies of an eleven-page long story she wrote "just because she felt like it." ...she said she was still working on it and it would probably get a lot longer—she said she was thinking about making it into a whole book. [148] ...if there are spares available, kids in the PASCAL class that want to continue working at home can take one [laptop] home if they are going straight home after school. She said a kid who has been doing marginal work all year has started taking one home, and yesterday he brought in a draw program he said he worked on for three hours, which draws a castle. [269]
Excitement • responding to novelty • can motivate technical know-how	The boys in back discovered that, after they had typed "Date" or "time" at the C prompt and entered it, they could press the right or left cursor keys and the word would type itself out again. They asked me why that happened and I said I didn't know—they were very excited—"we're finding stuff nobody else knows!." [111]

Role of Teacher

The Positive Role of Teacher theme (15.9% of total observations) allows the observer to keep track of the teachers' practices, their interactions with students, and how they shape their students' educational experiences. This theme has three subcategories:

- *Promoting multiple roles and uses for the laptop computers*, encouraging integrated and selective use of technology and other resources; supporting student access to the technologies; looking for new resources;
- *Stressing supportive, responsible, collaborative relationships*, encouraging personal communication among teachers and students; concern for the social well-being of the students; finding opportunities for them outside the class room; sharing decision-making with students; stressing student responsibility and accountability; learning from students and other teachers
- *Encouraging reflection by students*, through practices including problem-solving, group work and interdisciplinary work.

Negative Role of Teacher accounted for 5.4% of the total observations, and was related to negative outcomes in difficult situations including balancing the need to control classroom activity while allowing independent student work, and responding to (or avoiding) conflict among students or individual students' detachment from classroom proceedings.

Know-How

The positive Know-How theme (15.7% of total observations) reflects the role that technical competence (or lack of competence) plays in the day to day workings of the project. The three subcategories that emerge here are:

- *Knowledge of technical issues*, which facilitates ease of use in the classroom, and supports independent exploration of technical resources;
- *Ability to solve technical problems for self and others*, which includes student-teacher, student-student, and teacher-teacher problem-solving and inter-reliance;
- *Being able to teach someone else a technical skill*, which suggests independence from constant technical support and the presence of multiple teaching roles among teachers and students.

Negative know-how accounted for 4.6% of the total observations, and included frustrations or failures caused by inadequate knowledge about a technical issue and logistical complications caused by uninformed decision-making.

Subcategories	Examples from Field Notes
Promoting multiple roles and uses for the laptop computers • integrated and selective use of technology • supporting student access to the technologies • looking for new resources	Sally had them start brainstorming, on paper, in their table groups, about writing letters to Kenny (the eighth grade vice-principal) about how to get the eighth grade to be better behaved and get more work done...[she] says she wants the kids to start thinking about using both paper and pencil and the computer—to brainstorm and write in different phases, and to use whatever medium is most comfortable for both activities. [140] Marianne talked to the kids about the printers, and said that she and Sally would arrange to be in the room before and after school so they could print any work they had for other classes. [54]
Stressing supportive, responsible, collaborative relationships • personal communication among teachers and students • concern for social well-being of students • sharing decision-making with students • stressing student responsibility and accountability • learning from students and other teachers	...Sally said Cassie has missed some school, and told her once that she overslept so she just skipped the whole day. So, Sally said, she sent Cassie a "wake-up call" (her words) on the PULSE system encouraging her to stay on the ball and keep up with her work. [118] When people asked when it was due, M said she didn't really know, and they worked it out right there that given the amount of work they have left to do, it should be due on the 20th. Jamal commented that "she expects too much—this is too much work." [291] Sally announced that the typing tutor disks had come in, and asked the class how they thought they should be distributed—they decided together that each table should have one, and it could be signed out for several days at a time, but if someone else at the table wanted it the person had to bring it back. [109]
Encouraging reflection by students • stressing student problem solving • promoting group work • promoting interdisciplinary work	Marianne also asked them about what problems happened last time. They went through several and got to the problem of the seed configuration—some seeds grew up from the bottom and hit other seeds. She encouraged them to think in their groups about how to avoid that problem. [208] Marianne told me that she had decided to let the groups (tables) make their own decisions about what variables to use in the #2 plant germination project...she thought "it would be fun" to do it this way, and have the kids see what happens to each other's hypotheses. The groups are working together to come up with experiment designs. [201]

Making Things Work

Making Things Work (positive, 12.3% of observations; negative, 6.9% of observations) is the problem-solving theme, and is concerned with the process of identifying problems and finding solutions. Making Things Work frequently intersects with Know-How and Teacher Collaboration. It is also the theme with the highest number of negative occurrences in this study, and thus we have identified subcategories for both positive and negative occurrence.

Subcategories for positive occurrences are:

• *Time, space and money*—addressing and resolving the frequent limits placed on resources. Answering the question, "where do we want the technology to be, and when, and how will we plan what to do with it?"

• *Capacity of technology*—answering the question, "can it do what we need it to do?"

Subcategories for negative occurrences are:

• *Breakdowns* of the technology and subsequent work involved in having hard ware repaired, or in trouble-shooting software

• *Limitations*—determining that the technology will not able to do (or is not available to do) what someone wants.

Discussion

It is not surprising that Know-How and Making Things Work are central to the first year implementation of a technology project, as logistical and practical issues about space, time, and technical knowledge crop up frequently. The prominence of Know-How, however, is important in that it was usually related to *positive* activities or interactions. The prevalence of the positive subcategories in this theme underscores the fact that effective group practices for problem solving, availability of appropriate assistance and expertise at the right time, and willingness to explore and solve problems individually were critical factors contributing to the project's successful implementation. Overall, the Project PULSE team had a remarkably smooth introduction to a group of significant new tools and a large number of new routines, any of which could have become obstacles to less flexible,

less organized, or less well-supported teachers.

There are many more negative occurrences in the Making Things Work theme. This is largely due to hardware breakdowns and consequent hardware shortages. Several factors ameliorated this problem, which remained serious but did not ultimately cause the project any major setbacks. The computers were under warranty for the entire school year, which eliminated the cost of service for repairs. Technical support was available in-house for minor repairs, so many break-downs were short-lived. And finally, there were enough machines not permanently assigned to students that "loaners" could go out to students whose "own" machines were being repaired.

The prominence of the Role of Teacher theme (positive and negative together constitute 21.3% of total observations) is consistent with findings from other school-based research done by the Center for Children and Technology, which suggest that introducing new technologies into the classroom inevitably raises many challenges for teachers, and can have a significant positive impact on their teaching practices (Carver, in preparation; Schofield, Evans-Rhodes, & Huber, in preparation; Sheingold & Hadley 1990; Rubin & Bruce, 1990, 1986). We also observed that different teachers interpreted and orchestrated the use of technology in different ways (Honey & Moeller, 1990). Although Sally and Marianne stressed different specific uses of the computers, overall they both emphasized tool-based aspects of computer technology. They used the computers purposefully and constructively in situations where the technology could facilitate student work.

Subcategories	Examples from Field Notes
Knowledge of technical issues • facilitates ease of use • encourages further exploration	The problems with the printers are usually minor and the kids are very good at trouble-shooting. Jerry is usually overseeing other people's work and he volunteers to finish printing jobs for people if they need to go do something else...the printing tables often become a very social spot, and several extra people will be hanging around talking with and helping the people who are working. The kids also are very fluid with their disks, loaning each other whatever is needed and then sorting out their disks at the very end of the period. As science class started, Marianne told the kids to transfer into Works any work for the lab report that they still had in Bank Street Writer, and to print out the first four sections of the lab report to be turned in today...She explained that she would review these to make sure that everyone was on track to get the whole project done. [290]
Ability to solve technical problems for self and others • inter-reliance among students and teachers	The kids were listening to Sally at the beginning of the period, but also attending to loading up BSW. Kijuana was energetically cleaning her screen and keyboard, saying "someone's been touching mine!" I saw computers being exchanged several times this period—it's the first time I've seen it. When someone has a question, another student may just say "let me see," and trade computers, fix the problem, and hand it back. The girls at Kijuana's table were looking over their journal entries while Sally talked—I saw them cutting and pasting, and one girl explained to another how to delete a file. Kijuana and Chris were clearly absorbed in writing while Sally talked. [47] At one point in class, Sally forgot how to get to the top of a document and asked the class. A number of kids told her "control-home" right away. [331
Being able to teach someone else a technical skill • independence from technical experts • multiple teaching roles for teachers and students	Jeremy and Brandon taught the class how to use the graphing components of Works—Brandon's notes were up on the board. I asked Jeremy about it, and he said yes, they did that, but "he has one way and I have another way" of explaining how to do it, so they explained both, and some people are using Brandon's way and some people are using his. [326]

Overall, the themes that emerged as dominant in this research suggest that even for experienced, well-organized teachers using a portable, generally convenient piece of technology, integrating that technology into the classroom challenges their *planning skills and habits*, and *engenders change in their teaching styles*. These changes were sometimes quite concrete—for example, as telecommunicating fostered increased communication among teachers and between teachers and their students, they received more suggestions and more feedback, which influenced them in making specific decisions about day-to-day classroom activities. Some changes were more dynamic and less deliberate—the portability and privacy of the laptops, as

Subcategories	Examples from Field Notes
Positive	
Time, space, and money • Where do we want the technology to be, and when and how will we plan what to do with it?	Karen said she put in writing their request to the powers that be that they all have the same schedules next year, and that she cc'd it to everyone she could think of. [339] Since they weren't able to finish collating the data today, M told them to try to finish tomorrow, so the data can be sent to Kentucky tomorrow afternoon—she also suggested that they finish it either in English ("ask Mrs. Boyd if you have free time if you can work on this), or to do it at the same time as they work on the M&M activity tomorrow. [190]
Capacity of technology • Can it do what we need it to do?	We talked about introducing Works, or maybe introducing the non-tcomm functions of it, through this botany unit...M pointed out (I think she thought this might bother us) that since these kids don't really know graphing at all, that it would probably be more meaningful to them if they graphed by hand at first. [100]
Negative	
Breakdowns of the technology • tracking and recording equipment failure • arranging for repairs of hardware • trouble-shooting software	Marianne told me they've begun having some hardware problems. Amr and Kijuana's batteries seem to be dead, Wesley's escape and Fl keys are stuck, Chris has one stuck key, and the left-most cursor-column on Michelle's screen is blank. I asked the kids as a group if anyone else was having hardware problems, and reminded them to tell me if anything went wrong. [53]
Limitations • determining if the technology will be able to do what is needed	Wesley asked if there was any way to avoid switching disks...the kids have to switch back and forth between their personal and program disks while they're working in Works. M said he could save his file on his Works disk if he wanted, but that otherwise no, there was no way around it. [274]

According to the thematic analysis, the only positive themes to occur infrequently were Student and Teacher Collaboration. This low rate of actual acts or periods of collaboration, in spite of a number of curricular and pedagogical shifts toward collaborative planning and learning, is also consistent with other research findings which suggest that collaborative intentions and the introduction of group projects significantly predates actual substantive collaborative activity in technology-rich classrooms (Brunner, in preparation, 1992), and that it takes a significant period of time—five to seven years on average—for teachers who use technology in the classroom to become expert implementers of technology-based activities (Sheingold & Hadley, 1990).[3] The Project PULSE teachers views of themselves as teachers, as well as their actual practices, did move toward a collaborative, student-centered, project-based model, and the technology appeared to play a facilitating role in this regard. However, as the teachers moved in this direction, many of the concerns and challenges of doing collaborative work surfaced. Meeting these challenges (i.e., allowing students to conduct their own scientific experimentation while ensuring that they complete the project with an increased understanding of scientific thinking and methodology) requires the acquisition or discovery of a number of new skills and sensitivities. For example, teachers need to plan group activities and project research that can take place within the constraints of forty-minute periods; they need to understand and respond appropriately to the very different levels of understanding that students bring to inquiry-based investigations; and they must wrestle with new questions about how to assess a different kind of student product. A number of these issues are detailed below in our discussion of project-based activities.

well as their one-to-one correspondence to the students, affected teacher-student interactions while students were writing. And other changes were more broadly relevant—for example, since all students had constant access to integrated writing/graphing/databasing software, Marianne was able to significantly rethink her science curriculum, increasing her focus on authentic experimentation and independent work. These observations are consistent with other research on the impact of technology integration on teaching practices (Sheingold & Hadley, 1990). The introduction of the laptops to their classrooms and homes offered a combination of new opportunities and new obstacles that pushed the PULSE team's pedagogical habits in new directions, which will be explored later in this report.

Project-Based Work

Over the course of the school year, students became increasingly involved in project-based work. The constant availability and portability of the laptops, combined with the integrated word processing, data collection and analysis, graphing and telecommunications capacities of the software, facilitated this development.

Science Projects

At the beginning of the school year, Marianne had clear beliefs about what kinds of activities were important for students, and a great deal of experience in finding successful ways to translate often-abstract science concepts into meaningful experiences. However, much of the curriculum she had to cover was very traditional material—isolated definitions and diagrams that did not lend themselves easily to the kinds of real-world, hands-on teaching that she preferred. In other words, while Marianne stressed hands-on work, and frequently devoted much of the period to independent work, most of the material being covered was structured in short, self-contained units. Ties to real-world experience were supplied by Marianne, and while she did this consistently and well, the constraints of the curriculum often made the bridges difficult to build.

The "Problem with Plastics" Project

Over the course of the year Marianne began to introduce new pieces of curriculum that she had never tried and which dealt increasingly with substantive experimentation, real data, and group work among students. The technology played a role in motivating and supporting her in introducing her students to activities like collecting authentic data (through the integrated software package), and interpreting that data in relation to a larger research agenda. In January, students participated in "The Problem with Plastics," a nationwide survey project which encouraged students to measure their families' rate of disposal of plastic products. Marianne found out about "The Problem with Plastics" on Learning Link, a regional educational telecommunications network. Students collected data with their families for a week, then pooled their data and sent it to the coordinating school, in Kentucky, via Learning Link. Completing this project required that students work in spreadsheets, gain experience in pooling data, and most importantly, base their work entirely on extracting information from their own surroundings. By monitoring family habits, taking trips to grocery stores and comparing packaging and unit prices, researching their community's recycling and garbage disposal policies, and discussing their findings in class, students were making connections between life issues and science concepts in a way that was new for them. In this project, telecommunications would provide an opportunity to share and collect data that would contribute to an understanding of waste and recycling issues across the country.

According to the original project design, the class was to receive compiled data from all participating schools with which they would compare their findings. This phase of the project never came about, because so few schools submitted complete data. Consequently, some aspects of the project, especially activities that would have stressed comparing disparate data and drawing conclusions from it, were absent from the process. But from Marianne's point of view, the project was still successful, because her students had begun to work in novel ways with real data collected from their own environments.

Seed Germination Projects

Marianne was sufficiently encouraged by her students' enthusiasm for this project to try a long-term (several weeks) seed germination experiment, a kind of project she had never tried before. Each student raised two kinds of plants in plastic jars, and used prose journals and a database of measurements to track the growth of the plants. This project required the students to gain a better understanding of database concepts they had briefly covered in "The Problem with Plastics," introduced them to new graphing concepts and technical skills, and for the first time expected them to move through the full process of constructing hypotheses, collecting data, observing outcomes, and drawing conclusions. Between early February and late March (while also covering other curriculum) students grew their plants and completed lab reports summarizing their results in prose, data, and graphs.

Encouraged again by students' engagement in this experiment, Marianne decided to try the experiment a second time, but with two important changes. Students would investigate the rate of growth for different plants in four different solutions—salt water, water with fertilizer, sugar water and tap water—rather than just in tap water—and, rather than having

each student do a complete experiment alone, students would work in groups, with each individual caring for a set of plants in one particular solution. Students developed hypotheses and wrote conclusions together, and shared data on their different plants. During the week before the complete lab reports were due for the final project, two students led class for a day, reviewing with the other students how to create their graphs in Microsoft Works. Marianne encouraged students to rely on each other for answers to questions, only intervening when groups were unable to come up with answers among themselves.

During the experiment the class designed their spreadsheets themselves. Once they had decided together what they would look like, and brainstormed a list of different solutions everyone would use for their plants, they spent a period in what Marianne called "organized confusion," setting up spreadsheets, mixing solutions, deciding in their groups who would use which solution, and beginning to formulate hypotheses.

Observations began on April 13th and continued for almost three weeks. Once the data was collected, students asked when their reports would be due; Marianne said "I don't really know." Together the class worked out what they had to accomplish in the last six weeks of school, and determined that the reports would be due at the end of May. Marianne had been discussing the steps of scientific inquiry with the class, and expected full lab reports from them, with a materials list, illustrations, complete data and all.

The teachers clearly perceived this project as differing significantly from typical styles of teaching and evaluation at Abraham Clark. The project was difficult for both the teacher and the students. The project was also time-intensive—because of other activities and curriculum that needed to be covered, students did not complete their lab reports until a month after they had finished collecting data. However, students have indicated in interviews that this kind of work, while difficult or confusing at times, is very different from what they do in other classes and much more interesting. As one student put it, "Ms. Monaco makes science more interesting than it actually is." The technology helped Marianne to move toward goals she had always had—of students shaping their own tasks and taking responsibility for their own learning—and to realize them more substantively than she had been capable of in previous years.

Student Learning

What were students learning from this experiment? One day, Marianne told the class that she was pleased with the materials and procedures lists students were writing—that they were providing lots of detail, and that detail is important in lab reports. When we reviewed drafts of their reports, many of the lists were detailed and lengthy—how ever, hypotheses were, in most cases, unclear or incomplete. In their final lab reports, many students' hypotheses did not reflect a coherent understanding of the question under investigation. Some hypotheses were grouped together with conclusions as a single statement; some were uninterpreted reports of events ("my plants did not grow at all"); some were entirely absent. Hypotheses like "We predict that the growth of plants will be a very good success" indicated that students were not focusing on the differences between the growth of plants raised in different solutions. This project required that students demonstrate an ability to construct and develop their own observations, and their own conclusions independent of in-class activities. Examinations of their draft and final lab reports indicate that many students moved successfully through the procedures of the project without really engaging with this process of creating and testing a hypothesis and drawing conclusions from observations and data.

Why were these students, in the midst of carrying out their own scientific experimentation, unaware of the hypotheses they were testing? The problem lies in how unusual, if not unique, this kind of project was in the educational experiences of these students. Students are constantly required to interpret, based on teachers' explicit and implicit expectations, what "counts" as valuable information in any given educational activity. Their experiences in traditional fact-based, textbook-oriented science courses have taught them that skills like accurate reporting and/or memorization of concrete, in-class information or procedures is generally what they are expected to display in order to demonstrate mastery, not the inductive reasoning and observation required for this experiment.

The kind of information stressed by students in these lab reports reflects the students' understandable interpretations of what they experienced in class during this project. For example, because blotter paper is expensive and Marianne had an extremely limited supply, she insisted that the class follow a strict procedure as they cut their blotter paper, simply so that a

minimum of the paper would be wasted. This kind of lock-step activity, which is most likely consonant with these students' previous experiences in science classes, and Marianne's controlling, forceful presence during the activity worked together to signal "This is important. Show me that you did this right." In contrast, in a post-project group interview, one group that had worked together reported that they "hadn't been listening when Marianne gave the definition of a hypothesis," so they didn't know what it was. One student had responded to the problem by leaving the hypothesis out of his report, an other had asked Marianne, who he said had told her, "it means what you think is going to happen." Logistical restrictions made it necessary for Marianne to devote class time to leading and controlling the mechanics of the experiment; simultaneously, she was not able to adequately introduce her students to the style of thinking required for this project—in this case, that a hypothesis not only "says what you think is going to happen," but why you think it is going to happen.

This example illustrates the difficulties facing a teacher who is just beginning a shift toward collaborative group-based learning. Although this is the kind of work Marianne values for her students, her students have no prior knowledge of her changing expectations. The curricular changes Marianne made require not only extra preparation in relation to content, but extra preparation for her students; making explicit to them the kinds of knowledge and activities that she considers valuable, and how to work toward those goals successfully. A teacher cannot reasonably be expected to even anticipate, let alone gain mastery over, this double burden (of new material and new expectations) in a single semester.

Assessment Issues

At the end of the year, Marianne was faced with a stack of reports, each one ten to twenty-five pages of procedures, descriptions, graphs, illustrations and data. Staring at the stack of them one afternoon, she commented "I have no idea how I'm going to grade these." We talked about that comment at a planning meeting we held over the summer. The project was difficult to grade for several reasons: because she had asked the students to take on far more process, both in the experiment itself and in the presentation of the report, than was usually expected of them; because the students were unaccustomed to working in groups, and she was unsure of how that had affected their work; and because of the discrepancies, present in every report in different ways, between the quality of the thought that went into the work and the quality of the structure and presentation of the experiment. One student, for instance, kept a detailed, scrupulous log describing every detail of the growth of her plants, but didn't mention anything about the rest of the plants in the group. Another gave a complex, well-thought-out hypothesis, but completely misconstrued the meaning of her own graphs.

All of these issues were completely understandable consequences of taking on a complex, involved experiment, particularly for the first time. While in some ways Marianne felt that the students had undoubtedly had a great experience and been motivated by the immediacy and authenticity of the material, she also had a lot of anxiety about "specific stuff," as she said—had they really learned what the parts of the plant are called? Did they really understand what a variable was? How could she allow them to do their own research and maintain any kind of a structure around the material they learned? Marianne felt strongly that ultimately it was her responsibility to make it possible for her students to learn what they needed to know. This kind of experimentation gave her far less control over making that happen.

English Projects

Story Exchanges

After having spent the previous summer acquainting herself with telecommunications, Sally was eager to involve her students in story exchanges as soon as they were familiar with their computers. Story exchanges are one of the most common educational activities carried out over long-distance telecommunications networks. Sally found the idea attractive because she stresses the value of writing to real audiences as often as possible. Her interest in a writing exchange matched up with a priority shared by the teacher team, which was a desire to create more structured activities involving the local bulletin board and long-distance telecommunications networks. They found a partner school in southern New Jersey through a mutual acquaintance, and chose to build the story exchange activity on a traditional assignment—writing Halloween stories to submit to the school literary magazine contest. With Karen's help, Sally corresponded with the partner teacher at the other school by giving him

an account on the PULSE bulletin board. Every student wrote an opening for a story and teachers at both schools collected them on disk and exchanged the files. Students then completed stories written by students at the other school. PULSE students printed out the completed stories and, after being introduced to a simple graphics program, designed covers for them. Additionally, the coordinating teacher from the other school created a booklet of all of the stories which was distributed to all the participating students. This project was the students' first introduction to telecommunications, and as a group they expressed a strong interest in the process that brought them these stories from students at an entirely different school.

Cultural Exchanges

During the second semester, Sally carried out a somewhat different kind of writing exchange. This project involved her ninth grade class—Sally, more than either Marianne or Karen, consistently tried to expose her other, non-PULSE classes to the computers and to telecommunications. Her ninth grade English class participated in a regional writing exchange exploring cultural differences among students from different schools. In the first phase of the project, every student wrote a brief description of themselves and their activities, based on a set of questions provided by the exchange. Each class was paired up with a class from another school. Students received profiles of students from their exchange class, and wrote a story or a poem based on the information.

Sally found this exchange to be less successful than the first. Three separate factors contributed to her judgment. Two were immediate obstacles involved in completing the project: technical difficulties (downloaded prose was poorly formatted and full of static, making it hard to read) and what she felt was the poor quality of writing of the students from the other school. The third problem was a lack of follow-up on the part of the organizers of the project. The project organizers had planned on carrying out on-line discussions for students about their experiences in the exchange, which ACHS students could not easily participate in because their was no phone line in their classroom, limiting their access to hands-on telecommunicating. Additionally, a booklet of student writing from the project which had been planned on was never produced, which left Sally feeling that the project had been less substantial than she had expected.

Sally's experience raises familiar questions about the difficulties of relying on other schools and outside coordinators to support telecommunications projects, as well as the advantages and difficulties of exploring cultural difference through telecommunications. According to several recent research studies, the factors that most often contribute to the success of telecommunications activities include planning, cooperat*ion*, and *relevant project goals* (Honey & Henriquez, 1992; Riel & Levin, 1990; Riel, 1989)—factors that are important to any shared learning activity. The kinds of problems that Sally experienced were typical of the obstacles that can arise when project designers do not take these factors adequately into account. Observing other applications of telecommunications technology during year two should add to our understanding of how teachers can best cope with these kinds of obstacles, which are just beginning to be acknowledged as a part of using this new tool for educational exploration.

Writing Analysis

Methodology

At the beginning of the year we hypothesized that the portability and privacy of the laptops, combined with the word processing capabilities, would facilitate student writing. We probed students' writing skills through an analysis of writing samples, and students' attitudes about writing through classroom observation and interviews. Three writing samples from seven students were selected for analysis, representing regular English assignments given throughout the year. Assignments used included a "Greek myth" invented by the student; a response to the question "What is English?;" original stories; a thank-you letter; and a letter to a friend asking the friend to quit smoking. Samples from each student included writing done early in the year, mid-year, and at the end of the year.

Writing samples were ordered randomly and presented without identification to two reviewers for analysis. Reviewers used the ESL Composition Profile (Jacobs, Zinkgraf, Wormuth, Hartfiel, & Hughey, 1981), an analytic, holistic evaluation guide intended to help evaluators profile a writer's "success at composing or 'putting together' the main elements of written

discourse into a connected, coherent piece of writing that communicates effectively." (p. 31) Each writing sample is evaluated according to five scales which are proportionately weighted according to their relative importance to the writer's ability to communicate successfully (content 30%, organization 20%, vocabulary 20%, language use 25%, and mechanics 5%).

Findings

Figure 5 presents a summary of the results of our writing analysis. Overall, the largest increase in scores occurred between trial one and trial two, and scores improved again slightly between trial two and trial three. At the first trial, mean scores for student writing samples was 58.7 on a 100-point scale; the mean score rose to 79 at the second trial, and rose again to 81.3 at the third trial. Interrater reliability was checked ($r = .80$), and scores were averaged for each writing sample, then averaged across subjects for first, second and third trials.

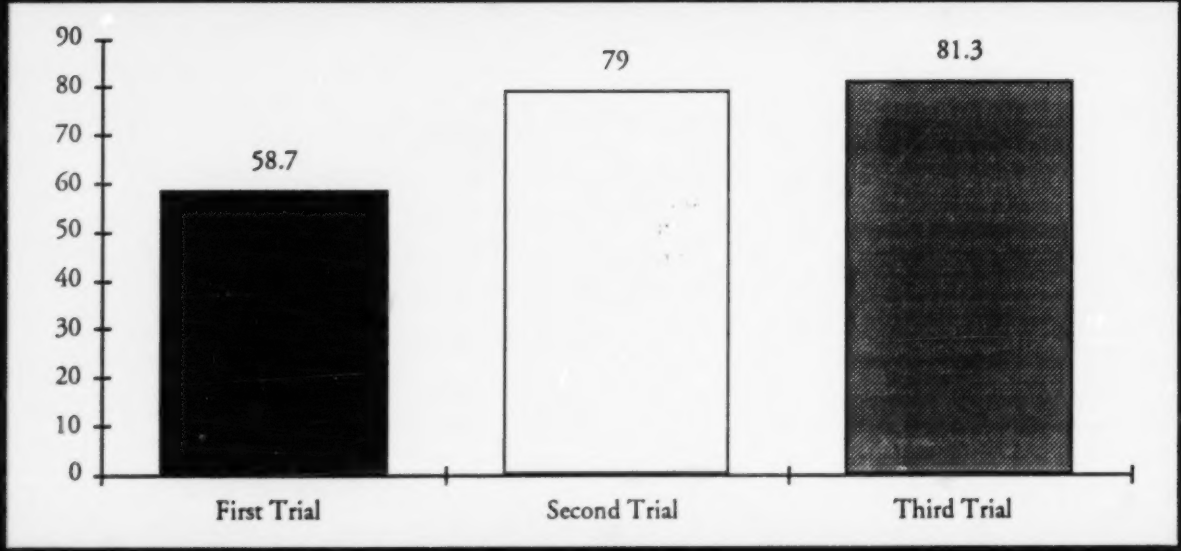
Discussion

The results reflect a growth in the overall ability of these students to communicate effectively through their writing. While we do not have a comparable, non-technology-using sample, and thus cannot attribute improvements in students' writing to the technology per se, there are a number of qualitative factors that suggest students were writing more and their writing was improving rapidly over time.

The laptops support student writing because they bring together two important sets of factors that both influence students' ability and willingness to write. First, word processing tools have been demonstrated to support students' writing development, particularly by making editing procedures less cumbersome (Daiute, 1985, 1986). Second, the portability of the laptops afforded the students all the flexibility and privacy of writing with paper and pencil—personal work, such as writing in journals, could happen with no risk of anyone reading drafts or works-in-progress or private pieces, and school work could be done in whatever environment, and at whatever time, was necessary or most comfortable for the student. Students could, and reported that they did, write in bed, in the car, at the dentist's office, or at their grandmother's house, always with full access to a word processor and all of their work in progress. The following quotes, drawn from student's written commentary on the project, reflect these aspects of their experience:

> I use my laptop just about everywhere, for just about everything. I even have my journal in there. When I am mad I type on it, and become relaxed,

Figure 5
Writing Skills Analysis



because it seems as if I'm talking to someone.

When I am at home I use my computer to show my family members how it works. One time I took my computer on vacation with me to have something to do and to show my other family members how it works. When I'm going somewhere and know its going to take a while, or if I just want something to do I take my computer right along with me.

Before, I never sat down and wrote a long story or wrote a journal, but with the laptop I do more of that. I think it's because I've always enjoyed working with computers and now that I have one, I can do what I've always wanted to do.

Throughout the year, many students made similar comments about their growing confidence and enthusiasm about themselves as writers. The dominant image in these and other students' comments about their experience in Project PULSE is of the laptops as private domains, as ever-present personal resources that supported their self-expression largely b*ecause* they were perceived as "owned," private, and personally meaningful.

Local Telecommunications

Overview of the Bulletin Board System

The Project PULSE Bulletin Board System (BBS) uses Galacticomm 2000 software and runs off of a free-standing (not connected to any local area network) 386 PC. The software was selected because it requires almost no initial setup and very little maintenance by the system operator. The software offers a number of features, including electronic mail, SIGs (special interest group spaces, or forums), classified ads, a polling capacity, teleconferencing (the capacity to support real-time conversation among multiple callers—the telecommunications equivalent of a conference call), and an information center for looking up information on other users or data on recent system use. The system was housed in a former copy room on the eighth grade hall. Two phone lines were installed in the room; during the day, one was connected to a phone for use by the PULSE staff, and the other was connected to the modem, and after school both phone lines were dedicated to the BBS. The system ran all day, every day, and was accessible by a local phone call for all PULSE students (local phone calls are free in New Jersey, so no cost was incurred by student families). The BBS is open-access; any caller can establish an account immediately the first time they call in. A standardized log-in of "first initial, last name" was established, and all students had passwords and unlimited access to the BBS. The twenty-five PULSE students, the PULSE teachers and researchers, and roughly a dozen others (including a high school student who worked as an assistant system operator, another teacher, several other students, and the Panasonic liaison for the project) held accounts on the system.

Getting Started

Students were taught during several class periods in December how to log on and off of the system, how to write, send and receive mail, how to upload and download files, and how to read the SIGs. Many of them also learned other skills on their own, such as finding out who else has been on line recently, and how to send messages to a number of people at once by creating a mailing list.

Getting the students started with telecommunicating was one of the most difficult hurdles for the PULSE teachers to get over. In October and November we talked through various ideas of how and when we might introduce the students to telecommunications concepts and the workings of the software. Unlike many other aspects of the project, finding a way to work this new information and these new procedures into regular class time seemed difficult—no plan for an introductory activity seemed quite right. Finally, for several days in mid-December, groups of students spent short periods of time working in the server room with Karen, creating their accounts and being introduced to the telecommunications component of Works. Once this was done, students began logging on from home. The system software largely took care of itself, with Karen and a high school student monitoring it in the evenings and on free periods. Soon so many students were logging on that a temporary fifteen-minute limit on calls to the system was instituted. This process of putting a great deal of effort into beginning to use a new tool and then discovering that students became authoritative users of it almost immediately was reminiscent of the time we had allowed in October for teaching students how to use word processing software. Students became fluent with the software almost immediately, just as many students became dedicated BBS users within days.

Patterns of Use

While regional telecommunications activities through Learning Link were an important aspect of several English and science projects this year, the local bulletin board system, commonly referred to as the "PULSE board," was much more significant to the PULSE team on a day to day basis. In five months, over six thousand messages were posted by approximately thirty active users of the BBS system. (See Figures 6 and 7 for some summary data about use of the local bulletin board system.) Of the twenty-five PULSE students, roughly twelve were very heavy users of the system, logging on anywhere from several times a day to several times a week. Eight PULSE students used the system occasionally, and five did not use the BBS at all (in a few cases, students were only able to use the BBS from within the school because they did not have working phone lines at home). The BBS was used most frequently for sending and receiving private e-mail, but many users also became familiar with other functions of the system. Teleconferencing, posting and reading messages in the SIGs (both announcements from the teachers and informal exchanges), posting classified ads, surveying directory information, and chatting on the teleconference were all common activities for many students and adult users.

At the beginning of the school year, the research team decided to limit the data we would collect from the BBS. We wanted all private communication to remain unmonitored, in order to maximize the legitimacy of the system as a space which was truly private and accessible to students. Consequently, we did not collect or monitor the content of messages exchanged between students, between teachers, or between students and teachers. Our interpretation of the PULSE team's use of the system is based on log on/log off data collected through the BBS software (which reports who was using the system when, but not their specific activities), verbal reports from students and teachers, and e-mail to the researchers from project staff and students. All student-student, student-teacher, teacher-student or teacher-teacher messages cited here were voluntarily forwarded to the researchers (see the appendix for some sample messages). Consequently,

Figure 6
Local BBS Logons (Total Logons = 735 between 3/9/92–5/18/92)

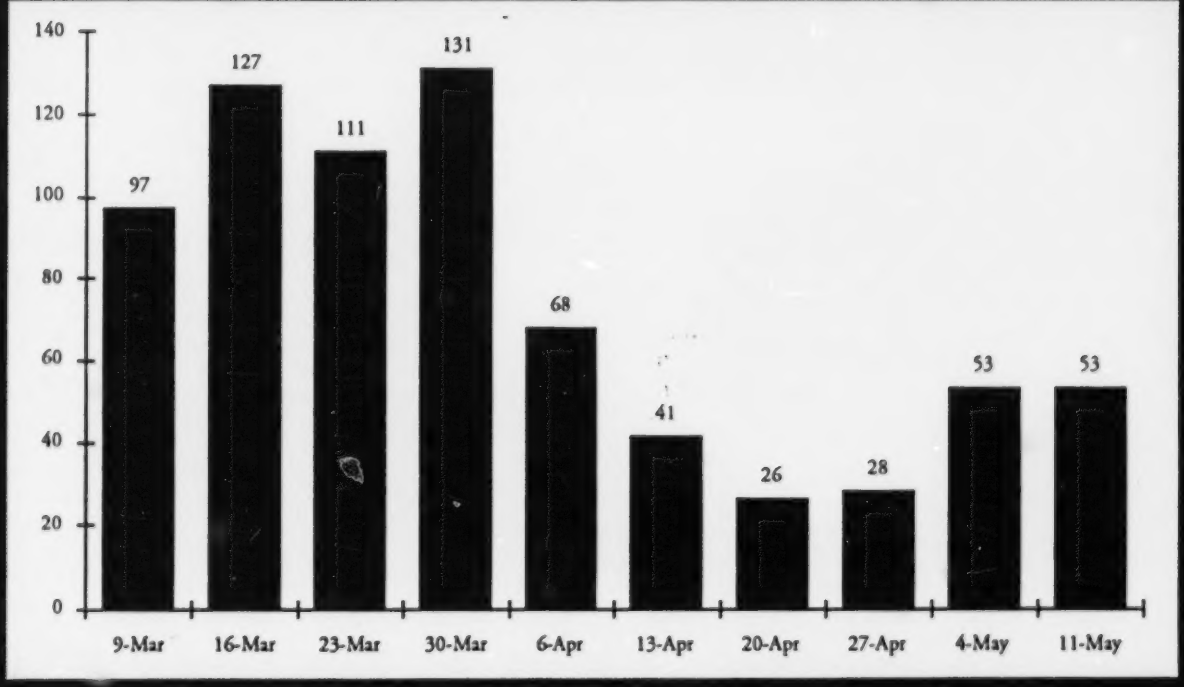
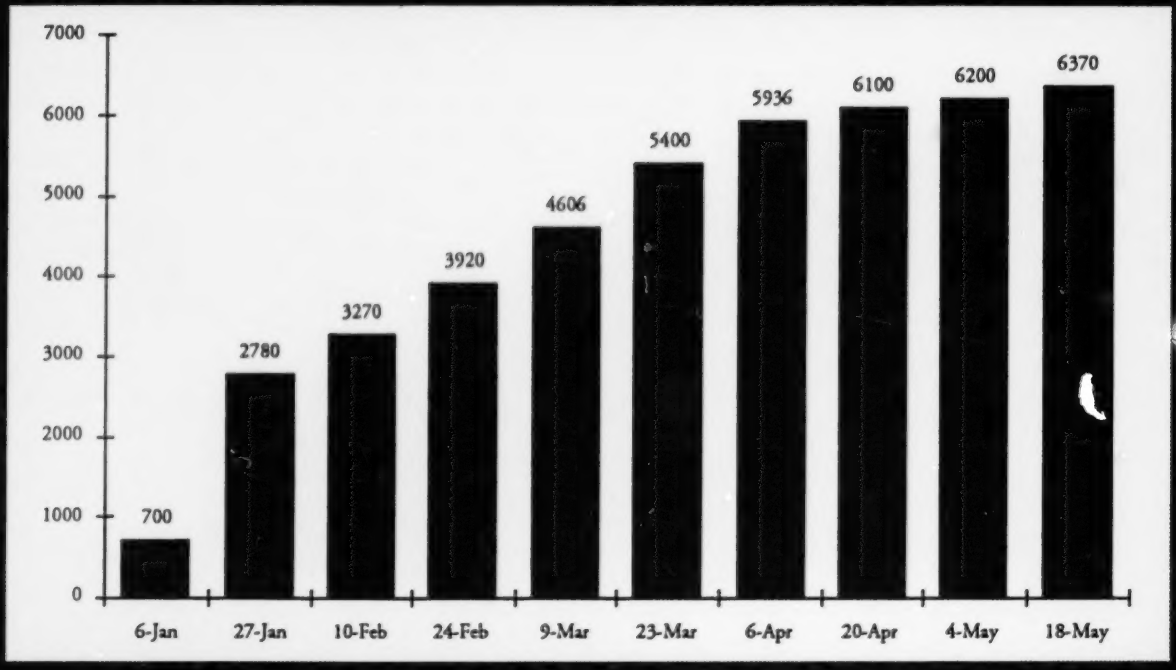


Figure 7
Local BBS Messages Posted



while we cannot provide any detailed information about the nature of the exchanges on the BBS on a day-to-day basis, the frequency data and information gathered from system users gives us some information about how students and teachers chose to incorporate this new communications media into their lives.

Student Use

The PULSE students accounted for almost two-thirds of all system use during the 1991-1992 school year (see Figure 8). A core group of regular student users, about a third to half of the class, accounted for the majority of this use. While this group included the three students with the highest "techie" status in the class (two of those three were the two white boys in the class), it encompassed a range of students, both boys and girls, with varying interests, degrees of academic success and social status. The public messages generated by this group (in SIGs, classified ads, and distributed messages) give us some idea of the attitudes they brought to their electronic communications.

A month or so after the BBS became active, "mystery" accounts began appearing on the system. People were logging on and establishing new accounts for names like "Sugar," "Hawk," and "Adonis." At first teachers and researchers were not sure whether these accounts were coming from hackers outside the community who had stumbled across the BBS, or from PULSE students, or friends of PULSE students. PULSE students questioned about the new practice suggested that "some people" in the class had figured out how to make new accounts. Each new character was short-lived, as Karen canceled the new accounts as quickly as she found them. These accounts were canceled because the teachers were concerned that the anonymity they provided would be exploited by some students for irresponsible or inappropriate kinds of communication. One account, however, kept reappearing: this was Batman, who for several weeks seemed to turn up everywhere on the BBS. His presence on the system finally generated this exchange in the SIG:

19-JAN-92 00:07
From: Batman
To: ** ALL **
To all my fans who don't know me. I am BATMAN your Super Hero from Gotham City here to protect you!

19-JAN-92 16:34
From: Ktate
To: Batman
Who is Batman
??????????????

27-JAN-92 19:11
From: Kalexandr
To: Batman
shut-up

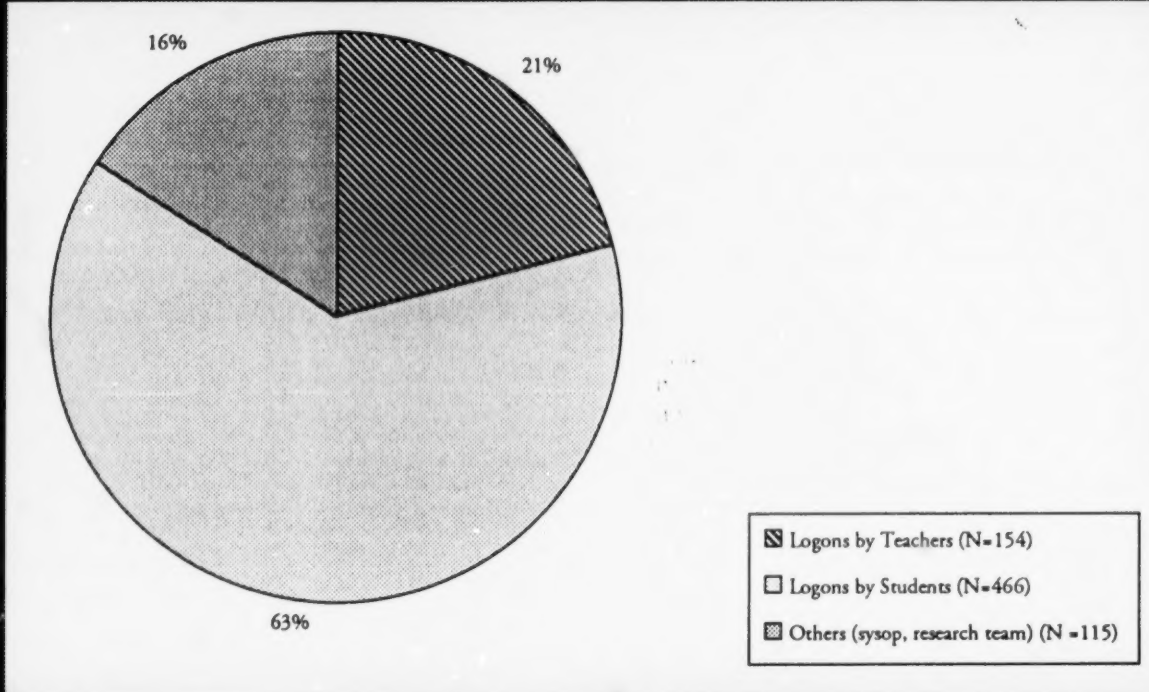
28-JAN-92 16:19
From: Tbland
To: Jhowlett
Jerry Flowers is Batman!

14-FEB-92 18:45
From: Wragland
To: Ktate
Batman I just want to tell you that you have people who know who you are so show yourself! Or I, Darkwing duck, the terror that flaps in the night, will catch you and bring you to justice.

14-FEB-92 19:26
From: Batman
To: ** ALL **
I am looking for a Robin and a Alfred. Call now on the telecommunications for an interview. I can't give personal interviews to protect my identity so send me a message on the telecommunications now!

As Batman's true identity became known, he eventually faded from view. However, this exchange represents a kind of expression that takes advantage of

Figure 8
Logon Activity by Group (Total Logons = 735 between 3/9/92–5/18/92)



the anonymity and sense of privacy that telecommunicating can afford users. It also suggests that a considerable number of students may have really found this space an accessible, private, and safe means of communication.

Teacher Use

Throughout the school year, the teachers reported and demonstrated enormous enthusiasm for the bulletin board system. For them, the system offered two main benefits: a solution to the chronic problem of poor channels for communication, traditionally one of the most difficult obstacles to successful teacher collaboration, and it encouraged private conversation between themselves and their students, which they reported was enormously rewarding. Over the course of the year they moved from being complete novices with some anxiety about exactly what role this new technology would take in their classrooms, to competent, enthusiastic users who felt that their local system offered a distinct, meaningful forum for communication.

> I had some fears about the kids using telecommunications in lieu of having face to face conversations with each other - like it's very easy to sit in front of the computer screen and talk about things that you might be embarrassed to talk about with someone face to face, which can be a good thing, but at the same time I was worried that it was going to isolate, that the kids would spend more time with this machine than with actual contact between each other. But I don't think that was the case. Because I think through the computer they became closer, and I think it broke through a lot of the boundaries and it allowed them to be more open in the classroom or with each other on a personal level. Like it allowed them to be more intimate than they might have been without the computer. Because we tend to wall ourselves into these little cubbies, and I thought the computer might do more of that, but I think what it did was broke down barriers between people faster, so it allowed people to become - friendships started a lot quicker, it just seemed like the kids accepted each other more than might normally happen in a classroom without the use of the computers, and I was kind of surprised by that. (Marianne, July 1992)

Telecommunicating allowed the teachers to share ideas, encouragement, suggestions, and observations among themselves in a medium which was distinct from any other in a number of ways. They were more accessi*ble* to each other than they would have been otherwise (through in-person meetings or by phone) because they were not impeded by the scheduling constraints of in-person meetings, they could send and receive messages from both school and home at any time, and messages for more than one person could be sent simultaneously. Their interactions were also *more easily mediated* because they were always able to choose when they would log on, and they were able to take whatever time was necessary to compose messages or to respond to messages from others. All of these factors made this form of communication important for a group of teachers who are deeply engaged with each other professionally and, as the year progressed, personally, but simultaneously needed to feel that they could control the degree to which the project intruded on their personal lives. The PULSE board made it possible to offer friendship, to be open and informal, because some of the risks of immediate interaction were removed. Consequently, teachers could exchange personal information such as stories of mishaps at home, discouragement about the political scene, or updates on their children's progress in college, as they worked together on their common project, without feeling that they had given up any control over access to their time or personal lives. Sally reflected on the impact of the PULSE board on relationships among themselves and between themselves and their students during an interview early in the second semester:

> Friendships, I'm sure, are being kindled. Because I know, just with Karen and myself, we telecommunicate every day, and we've just developed such a friendship, that might not have developed to that extent if it hadn't been though the telecommunicating. You're able to be very honest, you're able to be humorous, you're able to have fun, and you get hooked on it, as some of the kids have gotten hooked on it. (Sally, Feb. 1992)

The parents of the PULSE students were the only group of people that we anticipated would be active participants on the bulletin board who did not become significantly involved. This was project's most significant loss caused by the work action which was in effect throughout the school year. Although the teachers were eager to involve parents, and felt the bulletin board system would be an effective means of communication with them, the work action prevented them

from holding any workshops or training sessions for parents. Some students taught their parents to log on, and those parents did correspond periodically with teachers, but substantive family-oriented activities, or conversation among parents, did not take place on the PULSE board.

Motivations for Use

Methodology

By the end of the school year, our impression from many conversations, both in person and on line, was that both the teachers and many of the students had come to regard the PULSE board as a special path for communication. The data demonstrated that they were, in fact, using it heavily. It seemed particularly clear that while students were communicating frequently with each other, the board was most often mentioned in connection with teacher-student and student-teacher communication; that students were finding this medium particularly appropriate for communicating with their teachers. We conducted a small projective test with the students that was designed to help us under stand what students felt was distinctive about the PULSE board as a means of communication, and how it fit into choices they made about communicating with their teachers.

Students were given three moral dilemmas, each of which required that the character in the scenario contact their teacher. The first scenario involved a lost homework assignment which only the teacher could replace; the second presented a student who was nervous about an oral presentation and needed advice; and in the third scenario a student had chosen to tell a teacher that she/he knew who had stolen a piece of school property. We asked the PULSE students to recommend what Jane/John should do, how they should contact their teacher (in person, by phone, by e-mail) and why they chose that means of communication. Twenty students, ten boys and ten girls, participated (five PULSE students were absent the day the class did the exercise). The scenarios were designed so that, by our judgment, each one was best solved by one of the three different means of communication, but any one of the three would be a viable option if the student wanted to use it.

Findings

Tables 1 and 2 summarize the results of this test.

Table 1
Percentage of Students Who Chose Each Method of Communication for Each Scenario (N=20)

	Homework	Oral Report	Theft
In person	.55	.70	.45
Phone	.20	.10	.10
Modem	.25	.10	.40
Any/none	0	.10	.05

Table 2
Percentage of Students Choosing Each Mode of Communication Across Scenarios (N=20)

	Girls	Boys
In person	.40	.73
By phone	.17	.17
Modem	.37	.10
Any/none	.06	0

Scenario one:

At the end of the day Jane's teacher gave her a special homework assignment. As Jane walked out of school she looked in her notebook and realized the assignment had disappeared. Jane knows she has to do this assignment tonight. What should she do? Should she go back into the building and try and find her teacher? Should she call her teacher on the phone when she gets home? Should she use her computer and modem to leave her teacher a message? WHY?

For this scenario, half the students chose to talk to the teacher in person, and the rest were essentially split between calling the teacher and leaving an e-mail message. Some explained their choices with reference to influencing factors including not wanting to inconvenience the teacher, making efficient use of their time, other demands on their time including obligations to parents, and wanting to give the teacher a good impression of their level of responsibility. In the case of choosing face-to-face interaction, some students also felt it was preferable to receive the "real" homework (some physical piece of paper), rather than having the teacher describe it to them over the phone or by e-mail . The following quotes show the range of strategies students brought to the situation:

> First call her teacher, and if she has not picked it up then just use your computer and send her a message. Because you won't be able to find her in the

building. She could be anywhere. So you'll also get home on time. That way you can keep on calling or sending messages.

John should go back to school and find his teacher and get the assignment from her. That would be the right thing to do.

If he used the phone, when he got home and called his teacher to tell her he lost it, she's ask where did he leave it last, He'll say, "At school." She'd say, "Why didn't you come get another one." He'd have no excuse.

If he left a message on the computer she probably would not believe he lost it. She'd probably think he didn't want to do it.

This was the scenario which we predicted students would be most likely to solve through communicating face-to-face. The homework had to be done that night, and the surest way to get the assignment was to go back in the building and find the teacher. Students' choices for this scenario were informed by a number of different issues and a variety of reasoning processes.

Scenario two:

In two days Jane has to give a presentation in front of the entire class. She is terrified of having to stand and talk to everyone, but she knows that her final grade for the semester depends on this. Jane wants her teacher to know how nervous she is. Should Jane talk to her teacher after class tomorrow? Should Jane call her teacher on the phone in the evening? Should Jane use her computer and modem and leave her teacher a message? WHY?

For the second scenario, 70% of students chose in-person communication, with the rest evenly split between other options. We had seen this scenario as best solved by a phone call—the student needed to have a conversation, not transmit a single message (so the phone seemed preferable to an e-mail message), and a very nervous student might not want to risk waiting until the next day and possibly not finding an opportunity for a private, face-to-face conversation with the teacher. However, most students' responses assumed that the teacher would be available for a face-to-face conversation the next day, and stressed the personal quality of a face-to-face conversation as the most important factor in this decision. Some also extended the scenario by suggesting that speaking to the teacher face-to-face about a shyness problem would in and of itself contribute to overcoming shyness (as opposed to avoiding the issue by telecommunicating):

If John is really scared to talk in with an audience, John should get this problem out in the open. Leaving a message will not help him. He should confront his teacher face to face and talk and then he will probably gain confidence.

The students who did not choose an in-person conversation either chose to phone or leave e-mail because this would notify the teacher of the problem in anticipation of an in-person conversation the next day—"He should call her right away, which is in the evening. That way the teacher has more time to think it over." Two students felt the student should not contact the teacher at all: one said it "didn't make sense—why would you want your teacher to know you are nervous?" and the other felt Jane should "work it out for herself."

Scenario three:

Jane walked into class today and found her teacher very angry and upset. Someone had stolen all of the tickets for the prom which were supposed to go on sale that day. The teacher said that the prom would probably be canceled unless the tickets were returned. At lunch Jane accidentally overheard two students talking about having taken the tickets. Jane decides she has to tell her teacher what she heard. Should Jane write a note for her teacher and leave it on her desk? Should she tell her teacher in person? Should she use her computer and modem and leave the teacher a message? WHY?

We predicted that students would be most likely to choose to telecommunicate in response to the third scenario. In this case, we assumed that the privacy and security of e-mail would be important, and that the mediation it offered—that the teacher would probably read the message at home, outside of the school environment and at a distance from "Jane" herself—might be influential as well. However, student responses to this last dilemma were almost evenly split between in-person communication and leaving an e-mail message.

This result is distinctly divided along gender lines. Most girls preferred using e-mail, reasoning that the privacy it affords would protect them from teasing by other students (for "telling") or possible retribution. The boys, however, almost unanimously chose face-to-face communication, which they equated with courage, forthrightness, and "doing the right thing." The girls saw telecommunications as a pathway that would make it possible for them to say what they

wanted to say while minimizing the risk associated with doing so:

> She shouldn't leave a note because someone else might find it. She shouldn't tell her teacher face to face cause someone might see and over hear her snitching. She should tell her teacher through the computer, that way it will be between the two of them.

In contrast, the boys valued their willingness to communicate openly specifically because they felt that it was associated with risk: "He should tell her up front and that way he will be respected more and have a clear conscience."

In this scenario, mediation—the ability to communicate without face-to-face interaction, with time and physical distance separating the message sender from the recipient—is not necessarily interpreted as a good thing. But good or bad, it is acknowledged as a factor in both the boys' and the girls' decision-making in this scenario. As the girls actively sought out mediation, which for them implied safety, most of the boys recognized it as an attribute of communicating through the BBS, and actively rejected it. This distinct difference in values suggests that not only do students associate particular risks and benefits with various means of communication, but that those associations are complex and influenced by the nature of the information being shared.

Discussion

Analysis of the results of this task suggest that students perceive their local BBS as one among several viable means of communication with their teachers. They raised different motivation issues in connection with the different situations and different means of communication, indicating that their choices were informed by a number of issues and a variety of reasoning processes. Both boys and girls, and heavy, light and non-users of the system chose to telecommunicate for some of the scenarios. The results indicate that a diverse group of students did count telecommunications as a viable option for meaningful communication, and that their choice (or rejection) of telecommunicating was not simply based on novelty (or aversion), but on thoughtful evaluation of multiple factors involving efficiency, directness, self-efficacy, and honesty.

In practice, use of the PULSE board was not dominated by a single type or group of students, although the group that made most frequent use of the board included the most high-achieving students (two African-American girls) and the two white boys (frequently the most privileged and dedicated technology-users) in the class. In the projective test, however, communicating via modem was not only an option chosen by the class "techies" or even exclusively chosen by the "heavy users" group. For instance, an African-American female who was considered to be a below-average student with an "attitude problem," and not active on the BBS, chose to use the BBS in two out of three scenarios. In contrast, a white boy, one of the top achieving students in the class and a dedicated user of the BBS, chose to communicate in person for each projective scenario.

The moral dilemmas posed by the test were not intended to mirror actual motivations or patterns of use, and the profile produced by student responses did not, in fact, match up with real activity on the BBS. Instead, this picture of hypothetical use told us something about how students feel telecommunications fits into certain kinds of communication which we were curious about—in this case, communicating with a teacher about issues which are likely to be difficult on a personal level for the student.

In reference to gender differences in test responses, it could be that the boys prefer "getting it over with" by talking to a teacher face-to-face rather than waiting for a response, while girls want more differentiated, stylistically varied options for communicating. The unpredictable relationship between actual system use and responses on the task could indicate that the students most familiar with the board are also most familiar with its limitations, and are consequently discriminating in their willingness to use it in new situations, while students who never used it have only vague ideas of what it is best used for. Or they could mean that there are students who never had the confidence, or the training, or easy phone access, or "techie" friends, or whatever key factor was really necessary to get them on line, may also have been those who were most in need of a mediated, confidential line of communication with their teachers.

These findings may also be related to the way in which this class was introduced to telecommunications. Once the teachers had given the class an introduction to telecommunicating, students who reported having trouble using the system were given informal tutorials by other students, researchers or teachers

during available class time, but no further structured time was devoted to introducing students to the system. Because many students began using the BBS soon after being introduced to it, it seemed that their response to the BBS was the same as their response to new software had been at the beginning of the year—once they gained access to it, they simply took it on as a new tool to use as they liked. However, as we begin to learn something about what was distinctively valuable about the kinds of communication supported by the BBS—particularly private, mediated communication between students and teachers—and when we consider the enthusiasm for telecommunicating indicated by some of the students who were not active on the BBS, this image of "effortless mastery" may be worth reconsidering. If the kind of private communication afforded by the BBS was as valuable as teachers and students have indicated it was, then all students, and perhaps most particularly those who will not speak up in class to ask for help, deserve systematic, thorough support, to ensure that this new form of communication is truly accessible for everyone.

TECHNICAL ISSUES: HARDWARE LIMITATIONS AND PHYSICAL FEÅSIBILITY OF THE PROJECT

Careful, detailed planning of the physical and technical needs of the project was crucial to the teachers' and students' experience of successful innovation. Security, convenient and sufficient power supplies, and adequate hardware and software (including printers) were especially important issues. Arranging for these needs was time-consuming for the teachers but was facilitated by a supportive administration.

Having approximately seven "floaters," (computers that were not permanently assigned to a student) was also crucial to the viability of the project. Due to frequent equipment failure, students often needed to be loaned computers while theirs were being repaired. Because use of the computers was so intensive, students had to have continuous access to the computers; if extras had not been available to loan, use of the laptops by the whole group could not reasonably have been expected to continue.

Some equipment failure was external (stuck keys, broken latches), but the majority was internal (screen malfunctions, failed disk drives). Except for two cases of dropped computers, we did not find any evidence that students were mistreating the machines. They were, however, using them very frequently—a student using a laptop in four classes, after school and in the evening would turn the computer on and off at least six times, and use the disk drive a dozen times. If laptop use in schools is to continue and grow, hardware needs to be designed that will hold up to this kind of intensive use.

TEACHER INITIATIVES FOR PROJECT EXPANSION

As discussed earlier, motivation was a prominent thematic occurrence in our observations, and a particularly frequent form of motivation was taking initiative. Teacher initiative was often related to pursuing funding and equipment support which would further their goals for Project PULSE. Although these teachers described themselves previous to the project as "excited about trying new things," their efforts toward expansion were particularly significant because those efforts consistently required them to move outside of their school environment—in order to find funding they had to correspond with, talk with at conferences, or otherwise establish contact with utilities, corporations, and state government organizations. Their search for continued and varying support indicates both a commitment to the project as an on-going effort that belongs to them, not to an outside interest, and a willingness to find ways to interact with organizations outside of the frequently tightly-sealed world of the individual public school. Their role as teachers expanded, in their eyes, beyond their relation to their students, colleagues, and administration; they were able to act as part of a community that was new to their experience.

Their efforts at obtaining funding and publicity for Project PULSE have frequently been successful and include the following:

• The PULSE team was selected from a highly competitive pool to participate in The Global Laboratory, an international, year-long telecommunications project sponsored by the Technical Education Research Center. This project will take a major role in the Project PULSE curriculum this year.

• Project PULSE students, teachers, and researchers will be making a presentation at a Technology Summit at the new Liberty Science Center in January, 1993. The teachers are currently investigating possibilities for other in-state conference presentations, and for involving students in those presentations.

• Out-of-state conference presentations by the teacher team currently scheduled include:

- International Conference on Technology and Education, Cambridge, Massachusetts, March 1993;
- National Educational Computing Conference, Dallas, Texas, June 1993.

• The New Jersey State Technology Committee has used excerpts from a videotape about Project PULSE shot by the Center for Children and Technology in their own promotional videotape.

• PULSE teachers applied for and won two independent grants during the 1991-92 school year. These funds will allow for the installation of more phone lines, making in-class telecommunications possible from several classrooms, and for the further development of a project-based botany curriculum that stresses scientific thinking and data analysis.

CONCLUSIONS

This report was based on a year-long study conducted with a class of eighth graders, their English and science teachers and the school computer supervisor at a school in Roselle, NJ. A variety of data was collected and analyzed, including teacher interviews, classroom observations, samples of project-based work in science, writing samples, and projective tests exploring the impact of local telecommunications on patterns of teacher-student interaction.

When field notes were analyzed, four themes emerged as most significant to the overall success of the project: a high level of motivation for both students and teachers, teachers' facilitating and encouraging students' active appropriation of the technology, and a steady increase in technological competencies among the teachers, particularly with regard to telecommunications. The predominance of positive occurrences of these themes is related to a number of factors, including the experience and initial motivation of the teachers, careful and detailed planning of project logistics, and the flexibility and availability of the technology.

From the teachers' perspective, one of the most significant changes they experienced regarding the impact of technology on their practices was an ability to undertake more inquiry-oriented and project-based activities with students. For example, the portability of the laptops and availability of integrated tool-based software made it possible for the science teacher to undertake long-term, collaborative science projects with the students. This represented a significant departure from the previous years' curricula, and as a result students were able to gain experience with the kinds of tasks and procedures involved in scientific inquiry.

The other experience teachers described as highly significant in their experience of the project was the opportunity to communicate amongst themselves and with their students during off-hours through the local bulletin board system. The local bulletin board was used actively throughout the school year. It became a regular means for the teachers and for many students to communicate with each other and with the project staff. 5670 messages appeared over the course of five months, the majority posted by a core of approximately 25 students, teachers, and staff out of a total of 45 registered users.

In addition to using them for data collection and analysis and telecommunications, the majority of the Project PULSE students used their laptops as portable "diaries" in which they were able to keep personal and teacher assigned journals, write stories, and complete assignments. *Privacy, portability,* and *constant availability* freed students to integrate technology into personal, not just school-based projects. Based on a

holistic measure of students' writing scores for a randomly selected group of students, they improved markedly on their ability to communicate persuasively, organize their ideas effectively, and accurately use a broad vocabulary.

Because of the initiative of the Project PULSE teachers, this project has grown to encompass new resources, new curricula, and new partnerships. The PULSE team is now exploring complementary technology applications including telecommunications via the Internet, worldwide data exchange, and instructional television. They intend to use these new resources to support and expand the opportunities offered by the integration of laptops and local telecommunications into the daily life of teachers and students.

While the research demonstrates that laptops can have a positive impact on teachers' teaching and students' learning, without the following support in place this success would not have been possible:

- the commitment of the district superintendent to the success of the project. Consistent support from the superintendent's office made possible important adjustments in teacher schedules, classroom allocation, and physical plant (e.g. phone access and electrical wiring requirements);
- a room with adequate power supplies, accessible and secure storage space, and enough room for flexibility in arranging work space. Laptop computers need to be recharged on a regular basis, and need to be secure when not in use. They also facilitate flexible groupings of students and mobility in and around the classroom, and consequently are best served by a classroom large enough to accommodate those activities;
- on-site technical and conceptual assistance for the classroom teachers. Karen Warner played two important roles: she was able to introduce the teachers and their students to applications they were not familiar with, and she was able to identify additional pieces of software or technology-based activities that could support various aspects of the teachers' curriculum;
- adequate resources to sustain the project in spite of substantial and frequent equipment breakage. Each of three resources—on-site staff able to make minor repairs, warranties covering major repairs, and the availability of extra computers, to use as temporary replacements for machines being repaired—was crucial to sustaining the project. As of this writing, laptop computers are not generally designed for level of concentrated use they were subjected to in this project—until more robust laptops enter the market, a certain amount of breakage will be inevitable in an intensive-use project such as Project PULSE;
- shared planning time for teachers. While the local bulletin board system enhanced the teachers' ability to communicate with one another, regular, in-school planning time is still critical to the success of a collaborative venture. In addition to facilitating concrete activities like day-to-day decision making and sharing materials, daily shared planning time helps to establish a sense of community and continuity among team members;
- project structure that encourages responsibility among student participants. The students of Project PULSE took on a significant responsibility by becoming temporary owners of portable computers. They consistently used and cared for their laptops in a manner which lived up to their teachers' highest expectations. Establishing expectations early on in the project, by signing contracts and establishing regular routines, helped to make students feel that they were part of an on-going, significant school program;
- committed and enthusiastic teachers who took the initiative for shaping their own agendas for the integration of the laptops. These teachers were able to identify projects which would be appropriate to their own strengths, the capacities of the technology, and the needs of their students. They were consistently willing to learn new skills, to experiment in their teaching, and to support and learn from each other.

While different schools may have other needs or other kinds of support, these are minimal requirements that are necessary to the success of a project like this one. While some of these basic requirements are not much different from those for the introduction of any new technology (needing adequate power supplies), or for school innovation in general (shared planning time), others are more specific to the laptops, and to the flexibility and freedom they engender.

Footnotes

1. The other schools that received hardware grants through the *Laptops for Education* program were: Boonton High School, Boonton, New Jersey; Capital High School, Santa Fe, New Mexico; Frederick Douglass Academy, New York, New York; Lassiter High School, Marietta, Georgia; Mark Twain Junior-Senior High School, San Diego, California; Pinckneyville Middle School, Norcross, Georgia; and Thayer Junior-Senior High School, Winchester, New Hampshire.

2. An "observation" was defined as an interaction, a configuration, or a scenario observed by the field researcher, which illustrated or embodied one of a set of previously defined issues or themes. All observations were documented by the field researchers. Written observations for this project ranged in length from 5 to 392 words, averaging 82 words/observation.

3. Sheingold and Hadley's sample reported, on average, that it took five to seven years for them to become highly accomplished users of educational technology. This sample, however, should be considered to be the first generation of teachers to make substantive use of technology in their classrooms, who received little or no support during the earliest years of their technology use. As support for technology use becomes more widely available, through colleagues, district-level coordinators, or in-service or out-of-service training, this time span can be expected to drop. However, the general observation that becoming accomplished users of technology in the classroom takes a significant amount of time remains true.

References

Brunner, C. (1990, November). What it really means to "integrate" technology. *Technology and Learning,* 12-14.

Brunner, C. (1992). *Integrating technology into the curriculum: Teaching the teachers* (Tech. Rep. No. 25). New York: Bank Street College of Education, Center for Children and Technology.

Brunner, C. (in preparation). Lessons from the Lab School design experiment. In Hawkins, J. & Collins, A. (Eds.), *Design experiments: Integrating technology into classrooms.*

Carver, S. (in preparation). The Discover Rochester design experiment: Plans and outcomes for five designs. In Hawkins, J. & Collins, A. (Eds.), *Design experiments: Integrating technology into classrooms.*

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed.). New York: Macmillan.

Daiute, C. (1985). *Writing and computers.* Reading, MA: Addison-Wesley.

Daiute, C. (1986). *Using microcomputers in elementary language arts instruction.* Washington, DC: National Institute of Education.

Hadley, M., & Sheingold, K. (1993, May). Commonalities and distinctive patterns in teachers' integration of computers. *American Journal of Education.*

Honey, M., & Henriquez, A. (1992). *National survey of educators' uses of telecommunications.* Unpublished manuscript. New York: Bank Street College of Education, Center for Children and Technology.

Honey, M., & Moeller, M. (1990). *Teachers' beliefs and technology integration: different values, different understandings* (Tech. Rep. No. 6). New York: Bank Street College of Education, Center for Technology in Education.

Jacobs, Zinkgraf, Wormuth, Hartfiel, & Hughey (1981). *The ESL Composition Profile.*

Moeller, B., Reich, C., & Bell, L. (1991). *Computer networks as tools for supporting writing development in deaf students.* Paper presented at the National Educational Computing Conference, Phoenix, AZ.

Riel, M. M. (1989). Four models of educational telecommunications: Connections to the future. *Education and Computing, 5,* 261-274.

Riel, M. M., & Levin, J. A. (1990). Building electronic communities: Success and failure in computer networking. *Instructional Science, 19,* 145-169.

Rubin, A., & Bruce, B. (1990) *Alternate realizations of purpose in computer-supported writing* (Tech. Rep. No. 3). New York: Bank Street College of Education, Center for Technology in Education.

Rubin, A. D., & Bruce, B. C. (1986). Learning with QUILL: Lessons for students, teachers and software designers. In T. E. Raphael (Ed.), *Contexts of school based literacy* (pp. 217-230). New York: Random House.

Schofield, J. W., Evans-Rhodes, D., & Huber, B. R. (in preparation). The artificially intelligent tutor as a change agent: Unintended consequences for teacher-student interaction. In Hawkins, J. & Collins, A. (Eds.), *Design experiments: Integrating technology into classrooms.*

Shavelson, R. J. (1983). Review of research on teachers' pedagogical judgment, plans, and decisions. *Elementary School Journal, 83*(4), 392-413.

Shavelson, R. J., & Stern, P. (1981). Research on teachers' pedagogical thoughts, judgments, decisions, and behavior. *Review of Educational Research, 51,* 455-498.

Sheingold, K., & Hadley, M. (1990). *Accomplished teachers: Integrating computers into classroom practice.* New York: Bank Street College of Education, Center for Technology in Education.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 5*(7), 1-22.

APPENDIX

Sample BBS Messages

Msg: 15
From: Karen Warner
Subj: Telecommunications intro.
Date: Oct 30 1991 at 4:59pm

Dear All,

The kids are really eager to start telecommunicating so....I have a few ideas and thought we could do a little high tech brainstorming.

Idea 1—as we mentioned last time, we could 'act it out' a la Barbara Dubitsky, using the real bulletin board in the class and having different areas or folders for public and private messages.

Idea 2—The kids have seen the Host computer when they come up to print and have asked what it is. We could have kids dialing into our BBS from the classroom, have other kids watching what happens on the Host, and some more kids sending a message back to the kids in the classroom using the second phone line in room 216. Then they could meet together, report on their part of the process, and put it all together.

Idea 3—Give each group pictures of each of the 5 elements necessary to telecommunicate and some string and after an introduction have them assemble a model of a telecommunication system on the table.

OK, OK, these are just ideas to get us started. Responses?

Karen

Copies sent to:
Marianne Monaco
Sally Boyd
Margaret Honey
Katie McMillan
John Parris

E-Mail #2609 22-JAN-92 18:09 (Reply to #2381)
From: Mmonaco
To: Katie (private message)
Re: Garbage and Kentucky

Katie,
I can't believe that it happened the way it did, either. We will be starting survey II soon if I can ever get back on to Learning Link to find the time schedule. Lately it's been impossible. By the way I took pictures of the kids with their garbage so we have other documentation.

See you soon. Don't forget if you're coming out tomorrow check radio station WOR to see if we have a delayed opening because I heard of ice storm in the morning. Oh by the way the Board of Education did not ratify our contract last night. I mention this to you because our Association might recommend we do no "extras"—our parent meeting. We'll see what happens. Bye MM

E-Mail #4417 06-MAR-92 08:34
From: Mmonaco
To: Dmanager (private message)
Re: This weekend

Hi,
I just wanted to let all of you know that I'll be away this weekend—so don't think I'm giving you the cold shoulder. Marianne

E-Mail #4696 09-MAR-92 18:08 (Distributed)
From: Mmonaco
To: ** ALL **
Re: science work

Hi guys,
I'm so thrilled that almost everyone in class has all of their project work in. Keep up the good work. Let's try for 100%. Good luck on the hspt tomorrow. Bye Miss M.

E-Mail #5594 25-MAR-92 17:28 (cc: of #5568, Reply to*)
From: Sboyd
To: Dmanager (private message)
Re: STORY

Wesley, that's terrific! I can't wait to see your latest creation! Last night I attended a lecture at Kean College with my book club. We all read the same book, Praise Song for the Widow, and the lecture was given by the author. It was really interesting listening to her speak about how she gets her ideas for characters and stories and how long it takes her to write a novel.

I'm reading an intriguing book right now where the plot concerns a national cover-up about a space ship landing with aliens on board. That could be an interesting idea for you to center a mystery about. Or a missing person story could be an idea, too. In choosing a time period you could research information so that you could include pertinent details in the story. You could write about a time machine situation, perhaps. That's always fascinated me. Or perhaps try a mystery in the ghetto or out west on the range. Possibilities are endless. Just keep in mind that authors do research before they get too far into their endeavors. Again, so they have details of interest to add to their plots, characters and settings.

I really admire your writing talent and am so glad that you have been afforded the opportunity to use the laptops to further develop your writing aptitude. Talk to ya tomorrow! SBoyd

E-Mail #5938 29-MAR-92 16:10 (Fw by Sysop)
From: Dlopez
To: Dmanager (private message)
Re: DUKE # 1

Yo, Oliver did you see that 2.8 second shot by CHRISTIAN LAETNER TO WIN!!!! They won 104 - 103.